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Assessment of Potential Mineral Shortages: Chromium, Cobalt, and Platinum

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ASSESSMENT OF POTENTIAL MINERAL SHORTAGES:
CHROMIUM, COBALT, AND PLATINUM

By

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CHAPTER I

INTRODUCTION

During its 200 year history the United States has developed from a simple agrarian economy into the most highly industrialized nation in the world. Much of the early growth of American history was facilitated by the abundance of low cost mineral raw materials. This general abundance of raw materials continued into the twentieth century, but during the past few decades the low cost domestic reserves of many raw materials have become seriously depleted. In addition, advances in technology and industrialization have generated requirements for other mineral resources which the United States either does not possess or which are not economically available from domestic sources. Thus, the United States is no longer self-sufficient in mineral resources, and is becoming increasingly dependent on foreign sources of mineral raw materials.

This reliance on raw material imports has a direct effect on the ability of the United States' industrial base to support the needs of both the civilian and military sectors of the economy. In times of military or political emergency, sources of many critically needed minerals could be closed as in the recent oil embargo by the oil producing nations. Sheet mica, vital in the electrical and electronics industry, is imported from primarily three foreign sources with 89% of the United States' demand being supplied by India.[1] Likewise, the platinum group of minerals, important in many industries including the electronics and chemical, are primarily available only from foreign sources. About 52% of the 1972 United States' demand for platinum group elements was supplied by the Union of Soviet Socialist Replublics (USSR)[2]. Other minerals for which the United States is highly dependent on foreign sources are manganese, aluminum, chromium, cobalt and nickel to cite a few.

Both the economic and military strength of the United States are highly dependent on the maintenance of a strong industrial capacity and as such they are in turn becoming more reliant on raw material imports. If this flow of raw materials were to be interrupted for an extended period of time, the industrial base, the economic strength, the military capacity and indeed the national security of the United States would be severely jeopardized.

In his book, Strategy and Economics, Major General A. N. Lagovskiy, a Soviet military economist, indicates that there are no sharp boundaries between modern economic and military problems, and that an understanding of the economic factors of war is essential to the comprehension of the actual motive forces of war.[3] In assessing the military capability of the United States, General Lagovskiy concludes:

> Consequently the weakness of the economy of the USA, with all its strengths as a whole, lies in the fact that it either has no reserves of many materials that are important for war production inside the country, or has them only in small quantities. From this arises the unavoidable import of the raw material in quite large quantities.[4]

This report will review in detail General Lagovskiy's "weak link" as it pertains to selected mineral resources and will indicate some of the means available to assure the adequate and uninterrupted supply of these minerals necessary to meet the industrial and military requirements of the United States for the 1980's.

To understand the problem as it pertains to a particular resource, it is necessary to study the supply and demand constraints on that resource together with the geographic and foreign policy implications that might affect its continuous availability. This study will review the current situation as pertains to specific mineral resources, namely chromium, cobalt and the platinum group metals. Each of these minerals is vital to the needs of the civilian and military sectors of the economy and little, if any, of the demand is satisfied by domestic production.

It will be necessary throughout the study to use past data and projections on the supply and demand situations of various minerals. The elements of data used in this study have been obtained from United States Bureau of Mines publications, government studies and other sources felt to be reliable. The authors will not review in detail the techniques and bases for the individual projections or estimates, but they will be assumed to be accurate and realistic products of reliable research.

In examining the problem, this study will first review the background of the problem by briefly considering the history of the overall supply and demand for resources not only within the United States but worldwide. The review will highlight a few of the notable problems encountered in the recent past.

Upon conclusion of the brief historical account, the particular problems associated with assuring an adequate and uninterrupted supply of chromium, cobalt and the platinum group metals will be addressed. After the detailed description of the problem, a review of actions taken to date and their success will be examined. These individual detailed studies will be concluded with comments concerning future policies and actions to alleviate potential shortages for each mineral resource. In the final portion of this study, the Authors will draw some general conclusions and recommendations based on the individual detailed studies.

Before entering into the main portion of this study, the definition of three terms that will be used frequently must be clearly understood. These terms are: mineral reserves, mineral resources, and strategic minerals.

> Reserves are mineral deposits that have been reasonably well identified and that are sufficiently rich in grade to be worked profitably under existing economic conditions. Thus, reserves are a small portion of total resources and bear virtually no relationship to total mineral resources in the ground, or to amounts of mineral resources that may ultimately be recovered. Because of this relationship, reserve data is important only for the near future.5
>
> Resources include reserves, and also identified sub-economic resources, hypothetical resources, and speculative resources. Identified sub-economic resources are those that are known, but are too low in grade to be economic now. However, improvements in mineral technology can move them into the reserve category. Hypothetical resources have not yet been discovered, but are geologically predictable in known mineral districts. Increased exploration activity and new earth science theory and methods can move these resources into identified categories. Speculative resources are those thought to exist in other than known mineral districts. The possibility that speculative resources exist in a given region must be judged by broad geologic similarities or by statistical relationships with known mineral districts. Looking to the future, for the

middle and long-term, resource data are vastly more significant than reserve data.[6]

Strategic Minerals are those minerals essential to the national defense for the supply of which in war dependence must be placed in whole, or in a large part, on sources outside the Continental Limits of the United States, and for which strict conservation and control measures will be necessary.[7]

CHAPTER II

BACKGROUND OF THE PROBLEM

The large scale production and consumption of mineral resources is a relatively recent phenomenon. Worldwide production and distribution before the Industrial Revolution were inconsequential and did not expand rapidly until the latter half of the nineteen century. Since that time, worldwide mineral usage has risen at an exponential rate. For example, from 1900 to 1938, world mineral production and consumption exceeded that of all preceding history.[1] By 1950, the United States alone consumed six times the total world consumption by 1900. By specific minerals, consumption of iron ore rose three and one half times, copper usage increased three times and zinc usage increased four times between 1900 and 1950.[2] If these trends continue, as is expected, by the year 2000 the world demand for minerals will be five times greater than in 1973.[3]

In addition to this rapid increase in the production and consumption of individual minerals, there has also been a significant increase in the aggregate number of minerals necessary to support a modern industrialized economy. This demand originated as technological progress created new products and discovered useful applications for previously undesirable minerals. Titanium is an excellent example of this change. In 1948 total production of titanium was only three tons and the mineral was regarded as a contaminant in large bodies of iron ore. By 1971, production was in excess of 3.7 million metric tons and titanium was an essential component in the aircraft and aerospace industries. Similar changes in demand for other minerals have increased the number of industrially essential minerals from an estimated seven in 1900 to thirty-nine by the late 1940's and to forty-five by 1959.[4]

This proliferation in both the number and quantity of industrially essential raw minerals has introduced several problems for the modern nation; problems primarily arising from the varying levels of industrialization and development within the consuming and producing nations. The first of these problems is the accelerating demand for all mineral resources. The second is a realization of the unequal distribution of recoverable supplies of these same mineral resources. The result is that industrailized nations must continuously seek new sources of raw minerals to support the industrial and economic base of their economies. A further consequence is that industrialized nations must seek these supplies from a limited number of sources, some of which are often geographically remote and/or located within another sovereign nation. These conditions in turn require international trade to facilitate the acquisition of necessary mineral resources and establishes a mutual interdependence among nations. This interdependence was recognized as early as 1939 when no nation was considered totally self-reliant in essential minerals.[5] Since that time, interdependence among nations has increased.

The international dependence in minerals has historically introduced some potentially serious problems for the consuming nation. These problems have largely involved efforts by the producer or third parties to interrupt or limit essential mineral supplies to gain political, military or economic advantage at the expense of the consuming nation. Such interruptions and limits have occurred in both times of peace and war and have involved a wide variety of methods from overt military action to quotas and price manipulations. Some examples will clarify this point. The interdiction of bauxite convoys from South America by German submarines during World War II is an excellent example of denial to attain military advantage. German submarines sank 96 vessels and produced serious short run shortages of aluminum which, at that time, was vital to the United States' war effort.[6]

A more recent example is the attempts by certain copper producing nations to increase the price of copper on the international markets through cartel-like actions. This action attempted to use an existing international dependence in copper to gain an economic advantage of increased revenue to the supplying nations. Other examples can be given to demonstrate acts designed to yield political advantage. However, the citing of specific examples is less important than the realization that interdependence in resources increases the vulnerability of a nation to outside influence.

Now that a brief historical basis for the problem has been presented, a review of some specific trend projections in the demand and supply of raw minerals is in order. These trend projections are for the United States' production and consumption for the period 1972 to 2000. They are based on Bureau of Mines' projections and were extracted from two Department of Defense sponsored studies.

The first is a 1975 study entitled <u>Strategic Resources and National Security: An Initial Assessment</u>. This study was conducted by the Stanford Research Institute under government contract and covered a total of 74 different mineral resources used throughout the United States' economy, including defense applications. It estimated the consumption of 70 of these minerals by the year 2000.[7] It also ranked the 74 minerals according to their estimated importance to the economy as a whole and again according to their importance to national security. These categories will be used to project mineral demands for the upcoming 28 years: The estimated demand of all 70 minerals; the estimated demand of the 20 minerals considered most important to the economy, including national security uses, and; the 20 minerals considered most important solely from national security criteria. These categories were chosen to determine if significant differences are expected to develop between the aggregate demand and demand within the two specialized demand categories. The decision to consider only the 20 most important minerals in the two specialized categories was arbitrary.

From Table 1, the mean increase in demand for all 70 minerals is projected to be approximately 2.2 times during the 28 year period. This growth rate closely parallels the 2.06 mean increase expected for the 20 minerals ranked most important to the economy as a whole, but is somewhat higher than the 1.95 increase projected for the 20 minerals most essential to national security (Table 2). From these projected changes, it is obvious that the average demand is expected to increase at about 7% per year throughout the 28 year period, regardless of

TABLE 1

UNITED STATES CONSUMPTION PROJECTIONS 1972-2000
(QUANTITIES EXPRESSED AS UNIT VALUES)

	1972	2000
ALUMINUM	.4	2.3
ANTINOMY	.5	2.4
ARSENIC	.8	1.1
ASBESTOS	.5	1.5
BARIUM	.9	1.2
BERYLLIUM	.5	1.5
BISMUTH	.8	1.2
BORON	.5	1.5
BROMINE	.9	1.2
CADMIUM	.5	1.5
CALCIUM	.6	1.4
CESIUM	.3	1.7
CHLORINE	.5	1.4
CHROMIUM	.5	1.5
CLAYS	.5	1.3
COBALT	.7	1.3
COLUMBIUM	.4	1.5
COPPER	.5	1.5
CORUNDUM	1.0	1.0
DIATOMITE	.4	1.5
FELDSPAR	.4	1.5
FLUORINE	.4	1.8
GALLIUM	.4	1.6
GARNET	.5	1.4
GERMANIUM	.7	1.3
GOLD	.6	1.3
GRAPHITE	1.0	1.0
GYPSUM	.8	1.2
HAFNIUM	.7	1.3
INDIUM	No Estimate	
IODINE	.5	1.4
IRON	.8	1.2
KYANITE	No Estimate	
LEAD	.8	1.3
LITHIUM	No Estimate	
MAGNESIUM	.6	1.4

	1972	2000
MANGANESE	.7	1.3
MERCURY	.8	1.2
MICA (Scrap/Flake)	.5	1.4
MICA (Sheet)	2.7	.3
MOLYBEDNUM	.7	1.2
NICKEL	.7	1.3
NITROGEN	.3	1.9
PALLADIUM	.9	1.1
PERLITE	.5	1.4
PHOSPHORUS	.5	1.4
PLATINUM GROUP	.7	1.3
POTASSIUM	.5	1.4
PUMICE	.6	1.4
RARE EARTHS	.6	1.3
RHENIUM	.5	1.6
RUBIDIUM	No Estimate	
SAND/GRAVEL	.5	1.6
SELENIUM	.5	1.5
SILICON	.8	1.2
SILVER	.6	1.4
SODIUM	.6	1.5
STONE	.5	1.5
STRONTIUM	.6	1.4
SULFUR	.5	1.5
TALC	.5	1.5
TANTALUM	.7	1.3
TELLURIUM	1.0	1.0
THALLIUM	.5	1.5
THORIUM	.3	1.8
TIN	.8	1.2
TITANIUM	.6	1.4
TUNGSTEN	.4	1.6
VANADIUM	.5	1.5
VERMICULITE	.6	1.4
YTTRIUM	.5	1.5
ZINC	.7	1.4
ZIRCONIUM	.8	1.2
	43.6	96.6

PROJECTED CHANGE 96.6 ÷ 43.6 = 2.2

(Table 1 - cont'd)

NOTE: Actual quantities have been converted to a constant unit for each mineral in Table 1 to facilitate direct unit comparison.

SOURCE: Strategic Resources and National Security: An Initial Assessment, Stanford Research Institute, April 1975.

TABLE 2

UNITED STATES CONSUMPTION PROJECTIONS:
TWENTY MOST CRITICAL MINERALS 1972-2000

CRITICAL TO NATIONAL SECURITY	DEMAND 1972	DEMAND 2000	CRITICAL TO NATIONAL SECURITY & ECONOMIC ACTIVITY	DEMAND 1972	DEMAND 2000
MICA (Sheet)	2.7	.3	ALUMINUM	.4	2.3
MANGANESE	.7	1.3	IRON	.8	1.2
PLATINUM GP	.7	1.3	MAGANESE	.7	1.3
MERCURY	.8	1.2	GRAPHITE	1.0	1.0
TUNGSTEN	.4	1.6	COPPER	.5	1.5
CHROMIUM	.5	1.5	YTTRIUM	.5	1.5
ANTINOMY	.5	2.4	CHROMIUM	.5	1.5
TANTALUM	.7	1.3	PLATINUM GROUP	.7	1.3
FLUORINE	.4	1.8	TUNGSTEN	.4	1.6
GRAPHITE	1.0	1.0	MICA (Sheet)	2.7	.3
COBALT	.7	1.3	NICKEL	.7	1.3
ALUMINUM	.4	2.3	ANTINOMY	.5	2.4
TIN	.8	1.2	COBALT	.7	1.3
SILVER	.6	1.4	FLUORINE	.4	1.8
NICKEL	.7	1.3	MERCURY	.8	1.2
CESIUM	.3	1.7	SILVER	.6	1.4
ASBESTOS	.5	1.5	TANTALUM	.7	1.3
COLUMBIUM	.4	1.5	TIN	.8	1.2
INDIUM	No Estimate		LITHIUM	No Estimate	
YTTRIUM	.5	1.5	ASBESTOS	.5	1.5
	13.3	27.4		13.9	26.9

PROJECTED CHANGE 27.4÷13.3 = 2.06 PROJECTED CHANGE 26.9÷ 13.9=1.95

SOURCE: Strategic Resources and National Security: An Initial Assessment, Stanford Research Institute, April 1975.

demand category.

The consumption figures presented above raise the possibility that physical shortages of one or more essential minerals may occur by the end of this century. The data in Table 3 expresses supply as a ratio of recoverable reserves to cumulative demand by the year 2000 for 32 important minerals and further supports this conclusion.[8] For example, United States' recoverable reserves equal one half or less of projected cumulative demand for 24 of the 32 minerals studied. Perhaps more importantly, the United States has no recoverable reserves of 12 of these minerals and has recoverable reserves of 0.2 or less of the cumulative demand for 17 of the 20 minerals previously ranked highest on the criteria of national security importance and on the combined criteria of national security and economic impact. The conclusion from these figures is that the United States is presently deficient in recoverable reserves of many minerals and this deficiency is expected to increase throughout the remainder of the century.

One additional fact emerges from Table 3. This is the heavy reliance of the United States on imported mineral resources. In 1973, the United States imported more than 50% of 22 of the 32 minerals listed, with 100% of 5 of these minerals derived through import. Other

TABLE 3

RATIO OF UNITED STATES RECOVERABLE RESERVES TO CUMULATIVE DEMAND 1972-2000 BASED ON 1973 IMPORT LEVELS

MATERIAL	RESERVES/DEMAND
MICA (Sheet)	0.0
SILVER	0.0
BISMUTH	0.1
FLUORSPAR	0.1
MERCURY	0.1
GRAPHITE	0.0
TIN	0.0
ZINC	0.5
ASBESTOS	0.2
TANTALUM	0.0
TUNGSTEN	0.2
CADMIUM	0.5
CHROMIUM	0.0
MANGANESE	0.0
TITANIUM (Rutile)	0.0
NICKEL	0.0
PALLADIUM	0.0
ALUMINUM	0.0
COLUMBIUM	0.0
ANTINOMY	0.1
COBALT	0.1
THORIUM	0.1
PLATINUM	0.1
VANADIUM	0.2
IODINE	0.8
COPPER	0.9
TITANIUM (Ilemite)	1.0
LEAD	1.1
BERYLLIUM	1.2
MOLYBDENUM	2.0
TALC	3.0
MICA (Scrap/Flake)	10.0

SOURCE: Report, Review of Government and Industry Studies on Materials Supply and Shortages, Edward J. Dykman, Materials Department, Ship Research and Development Center, 16 December 1974.

sources identify this as a worsening trend by pointing out that within the past two decades net imports have grown from 11 to 15% of the total domestic consumption.[9] While this importation may represent only the use of more readily recoverable reserves rather than actual domestic shortages of reserves, it does highlight the United States' relative dependency position in mineral supply.

A summary of the mineral position of the United States indicates a present dependence on foreign sources for several essential minerals. It further indicates that scarcity of minerals is likely to increase by the end of this century. The potential scarcity arises because the United States is either physically without reserves of these minerals or possesses reserves that are unsuitable for recovery with present technology and economic conditions. Further, the United States is increasingly relying on import of minerals to meet her military and economic requirements, thus lessening domestic self-sufficiency. This approach makes the United States potentially vulnerable to political, military or economic influence by a foreign nation or group of nations through termination or limitation of vital mineral resource supplies. For this reason, each mineral resource which is important to our national economy and security must be evaluated with the intent of insuring an adequate continuing supply of these minerals. This study will undertake such an analysis for three such minerals; chromium, cobalt, and the platinum group metals.

CHAPTER III

CHROMIUM

Introduction

This chapter outlines some general uses of chromium within the United States at large. It then previews some important specific uses of chromium by three industries which support both the commercial and military sectors of the nation and which account for 96% of total chromium consumption within the United States. Projections of international, national and military demand are then presented along with current and projected reserves of chromium ore. The constraints on availability of chromium and the possibilities of substitution are also reviewed. Finally, some actions taken to date to alleviate constraints on supplies are reviewed and recommendations for future policies and actions are made.

Chromium is a white, crystalline, very hard metallic chemical element with a high resistance to corrosion. Chromite is the mineral ore from which all chromium is obtained. Chromite ore contains variable amounts of chromium (chromic oxide, Cr_2O_3), iron and aluminum, with other elements such as silica present in lesser amounts.

The ratio of chromium to iron in the ore, the amount of non-chromium bearing material in the chromite ore, and the physical character of the ore all determine the grade and uses of the ore. Three grades of chromite ore with corresponding uses are recognized. They are the metallurgical, chemical and refractory grades.

General Uses of Chromium

Chromium has attained an increasingly wide variety of uses throughout the United States' economy. These uses include metallurgical, chemical and refractory applications affecting a variety of products which are wholly or in part derived from chromium. The following list was presented in a 1975 study entitled Strategic Resources and National Security: An Initial Assessment, and is an excellent example of the many uses of chromium.

> Uses: Steel for motor vehicles, railroads, ships, jet engine parts. Stainless steel trim, hardware, fixtures. Structural steel as beams, decking, fencing, reinforcing. Pumps, tanks, pipe, tubes. Refinery, mining, chemical plant equipment. Tools. Domestic stainless steel products. Chromium plated appliances. Furnace linings, refractories. Plating. Yellow traffic paints, metal coatings. Treatment of hides, tanning operations, textile dyes. Corrosion inhibitors. Catalysts, drilling mud and compounds. Surgical metal. Mold and core making.[1]

This listing highlights the pervasiveness of chromium derived products in a modern industrialized economy, but fails to adequately recognize their criticalness. To understand this criticalness, it is necessary to review the different ores of chromium and to explore their use within the three primary consuming categories, the metallurgical, chemical and refractory. Table 5 summarizes chromite ore consumption by consumer group in the United States from 1963 through 1972 in the following grades:

1. <u>Metallurgical Grade</u>: About 50% chromic oxide, Cr_2O_3, a chrome to iron ratio, Cr/Fe, of over 3/1 and a hard lump physical nature.

Metallurgical uses account for over 60% of total chromium consumption and are increasing at approximately 5% per year. Metallurgical grade ore is converted to ferrochrome alloys which are used in the production of stainless steel, specialized alloy steels, including tool steel, and into various high-strength low alloy steels. Of these end items, stainless steel production is the most common, accounting for 66% of ferrochrome consumption. The specialized alloy steels are second in importance accounting for between 19 and 24% of chromium consumption within the metallurgical sector. The remaining 10 to 15% is alloyed with other metals to form high strength low alloy steels with exceptional heat and corrosion resistant qualities.

Chromium offers special advantages in each of these product categories that is not available from substitutes or is available with some performance or cost penalty. These inturn create special difficulties should the supply of chromium be interrupted. For example, stainless steel has many uses throughout the military and industrial sectors because of its unique resistance to corrosion. Yet, stainless steel can not be produced without the use of chromium. In the alloy steels chromium both hardens and strengthens the basic steel. The various specialized alloys are mainly used in non-strategic applications in construction (22%), automotive (22%), general purpose industrial equipment (12%), steel service centers (11.5%), power generating and distribution equipment (7.7%), rail transportation (5%), and forgings (5%).[2] The high strength low alloy steels are formed by combining chromium with other elements such as nickel, cobalt and iron to produce excellent heat and corrosion resistant materials. Such materials have been employed in two major industries, aerospace and petrochemical. Other substantial uses are in the manufacturing of heat treating equipment, stationary gas turbines and marine transportation equipment. Aerospace applications include wrought products and castings for aircraft airframes and engines. Like the production of stainless steel, no substitutes are known.

for chromium in some of these critical applications.[3]

In summary, certain non-strategic uses of chromium may either be substituted for or discontinued in times of national emergencies. However, applications that require corrosion resistance and those necessitating extreme hardening or heat resistance continue to demand an assured supply of chromium.

2. Chemical Grade: About 45% chromic oxide, Cr_2O_3, with 5% maximum silica, SiO_2, content. All ore shall be of a friable (easily crushed or crumbled into a powder) nature.

Chemical uses accounted for 16% of total chromium consumption by 1968 and were increasing at about 2.5% per year. Chemical grade chromium is primarily used in the form of sodium bichromate in pigments, plating, leather tanning, wood and water treatment, and numerous other lesser applications. Chromium pigments consume about one-third of the sodium bichromate used annually and are found in inks, paints and roofing shingles. This market is growing at about 2.5% per year. About one-fifth of the chemical chromium is used for decorative plating of consumer goods and for hard chromium plating of machine tools. This market is growing at over 3% per year. Leather tanning uses about 14% of all chemical grade chromium but is declining because of a reduced demand for leather. The remaining miscellaneous applications are as a corrosion inhibitor for metals, muds used in petroleum drilling operations, catalysts in various chemical processes, textile dyes, pharmaceutical chemicals, and water and wood treatment agents. These uses have in general shown a slow but steady growth trend and present a continuing, if not critical, demand for chemical grade chromium.

3. Refractory Grade: About 34% chromic oxide, Cr_2O_3, various other oxides of aluminum, silicone, calcium, and magnesium. All ore shall be hard lump in nature.

Refractory grade chromium is primarily formed into bricks and used for melting furnace linings in the open hearth steel producing furnace. It also has some limited uses in newer electric furnaces used for industrial heating applications as well as in the production of steel. Refractory uses accounted for 19% of total chromium consumption by 1968, but have been declining at about 5% per year as open hearth steel making is replaced by other methods. As this trend continues, refractory grade chromium becomes less vital to the continued military and commercial well being of the United States.

Demand

The basic types of chromium consumed within the United States have been reviewed, including the general uses within the three consuming sections. It is now time to quantify these uses where possible to determine the demand for chromium. To do this, the study will first present the current consumption of chromium both nationally and internationally and then project these levels of consumption through the year 2000. Finally, the uses of chromium by the defense sector projected for this same time frame will be explored.

National Demand. The United States consumed 900,000 short tons of chromite ores and 320,000 short tons of intermediate ferrochrome alloys in 1975. The metallurgical industry accounted for 64% of consumption, refractories 20% and chemicals 16%. By end item use, consumption was construction 22%, transportation 16%, machinery and equipment 14%, refractories 14% and all other uses 34%. Table 4 indicates the actual United States' consumption of chromite ores and intermediate ferrochrome alloys from 1965 through 1975. Table 5 further defines the consumption of chromite ores by industry from 1965-1972. These tables collectively indicate a gradual increase in the consumption of chromium which reached a maximum in 1974. In 1975 actual consumption declined in each industry compared with that of 1974, however, aggregate imports continued strong with consumer stocks increasing by approximately 66%.

TABLE 4

UNITED STATES CONSUMPTION OF CHROMITE ORE
AND FERROCHROME ALLOYS
(1,000 TONS)

CHROMITE ORES

1965	1966	1967	1968	1969	1970
1,582	1,461	1,355	1,316	1,411	1,403
1971	**1972**	**1973**	**1974**	**1975[e]**	
1,093	1,140	1,387	1,447	900	

FERROCHROME ALLOYS

1965	1966	1967	1968	1969	1970
395	416	368	369	387	343
1971	**1972**	**1973**	**1974**	**1975[e]**	
323	391	511	585	320	

e - Estimate

SOURCE: U.S. Bureau of Mines, Minerals Yearbook, Volume 1, Metals Minerals and Fuels, Various Years

TABLE 5

CONSUMPTION OF CHROMITE ORE BY PRIMARY CONSUMER GROUPS IN THE UNITED STATES
(1,000 TONS)

	METALLURGICAL INDUSTRY	REFRACTORY INDUSTRY	CHEMICAL INDUSTRY	TOTAL
YEAR	GROSS WEIGHT	GROSS WEIGHT	GROSS WEIGHT	GROSS WEIGHT
1972	727	224	189	1140
1971	720	193	180	1093
1970	912	278	213	1403
1969	898	302	211	1411
1968	804	311	202	1316
1967	866	310	179	1355
1966	828	439	194	1461
1965	907	460	217	1584
1964	832	430	189	1451
1963	632	368	187	1187

(1) Data may not add to total shown due to independent rounding.

SOURCE: U.S. Bureau of Mines, Minerals Yearbook, Vol. 1, Metals Minerals and Fuels, Various Years.

The future demand for chromium can be expected to continue this increase both because of new uses for stainless and specialized steels and because of the continued expansion of existing uses. The Federal Preparedness Agency of the General Services Administration projects the United States' demand for primary chromium will increase by 2.1% through 1980 and by 2.6% from 1980-2000. They further estimate that, depending upon the demand for stainless steel and the relative price of major substitutes, the bulk of growth will probably occur in the metallurgical uses with little or no growth in chemical and refractory use.

International Demand. International demand as expressed in world production of chromite ore has increased by over 37% in the period 1965-1975 (Table 6). This demand as estimated by the Federal Preparedness Agency will increase at a 2.8% annual rate through the end of the century as the underdeveloped and lesser developed nations become more industrialized.

Military Demand for Chromium. Chromium is indirectly of significant importance to the maintenance of a modern military. Chromium usage by the military closely parallels that of the civilian economy. A variety of chromium based alloy steels are used in transportation systems, construction products and general machinery and equipment

TABLE 6

WORLD PRODUCTION OF CHROMITE ORE
(1,000 SHORT TONS)

1965	-	5,370	1971	-	6,908
1966	-	4,843	1972	-	6,841
1967	-	5,041	1973	-	7,386 [e]
1968	-	5,444	1974	-	7,931
1969	-	5,865	1975	-	7,350
1970	-	6,672			

e - estimated

SOURCE: U.S. Bureau of Mines, Minerals Yearbook, Volume 1, Metals Minerals and Fuels, Various Years employed throughout the military establishment. The same indirect support relationship exists to a lesser degree for the chemical and refractory uses of chromium through paints, dyes, corrosion inhibitors, catalysts and refractory products.

Government sponsored research indicates that an average of 8.2% of the United States' consumption of chromium between 1963 and 1972 was devoted to defense uses (Table 7). This table further indicates an approximately stable ratio of defense to total consumption throughout the period. The authors found no specific projections of the future defense demand for chromium and assume none has been made because of its indirect use within the military.

Current Reserves. Based on geological survey, the 1962 free world reserves of chromite ore were estimated at 2,650,000,000 long tons.[4] This estimate was essentially duplicated in 1965 by the United States Bureau of Mines and the authors found few indications that it has officially been further revised. This amount is perhaps more meaningfully expressed as 1.4 times the estimated cumulative world demand for chromite ore between the year 1972 and the year 2000.[5] Table 8 identifies those free world nations with known reserves of chromite ore. It is important to note that South Africa (2,000,000,0000

TABLE 7

UNITED STATES DEMAND FOR
CHROMIUM USED FOR DEFENSE PURPOSES

(1,000 TONS)

YEAR	CHROMITE ORES	INTERMEDIATE FERROCHROMES	PERCENT OF U.S. DEMAND
1963	118.7	31.0	10
1964	101.6	26.4	7
1965	94.9	23.7	6
1966	116.9	33.3	8
1967	135.5	36.8	10
1968	131.6	36.0	10
1969	112.9	31.0	8
1970	112.2	27.4	8
1971	98.4	29.1	9
1972	79.8	27.4	7

TEN YEAR MEAN IN DEFENSE USE - 8.2%

SOURCE: *Strategic Resources and Nation Security: An Initial Assessment*, Standford Research Institute, April 1975 tons) and Rhodesia (600,000,000 tons) totally dominate the currently available free world reserves while the United States possesses essentially negligible reserves. Equally important to the total supply picture is the fact that the reserves of the Soviet Union and other Communist nations are unknown, even though the Soviet Union has supplied approximately one third of the world chromite ore for a decade.

Location of Reserves

Metallurgical grade chromite ores are found mainly in the Soviet Union, Rhodesia, and Turkey. South Africa reserves are primarily chemical grade while refractory grade ores come almost exclusively from the Philippines. A detailed survey of the actual sources and uses of chromite ore in 1967 is provided by Tables 8 and 9. By location, South Africa contains an estimated 63% of known free world reserves while Rhodesia has an estimated 32%.[6]

One additional implication of reserves must be evaluated. This is the fact that reserves are subject to change as certain market conditions change. To understand this condition, we must review the difference between reserves and resources and the possibility that resources may become proven reserves under certain circumstances. By definition, reserves are well defined and economically recoverable under existing conditions of price and

TABLE 8

ESTIMATED FREE WORLD RESERVES OF CHROMITE
(Thousand Long Tons)

COUNTRY	TOTAL	HIGHEST GRADE METALLURGICAL [1]	HIGH CHROMIUM [2]	HIGH IRON [3]	HIGH ALUMINUM [4]
So. Africa, Rep. of	2,000,000		100,000	1,900,000	
Rhodesia	600,000	(Total of both grades - 300,000		300,000	
Turkey	10,000		9,000		1,000
United States	8,000		400	7,400	200
Philippines	7,500		1,500		6,000
Finland	7,500			7,500	
Canada	5,000			5,000	
India	2,000		1,200		800
Melagasy Rep.	2,000		2,000		
Iran	1,000		1,000		
Other	3,350		2,325	200	825
FREE WORLD TOTAL	2,646,350		417,425	2,220,100	8,825

(Table 8 - cont'd)

(1) 45% Minimum Cr_2O_3, Minimum 3/1 Cr/Fe. This is the primary ore used for metallurgical purposes which account for over 60% of all chromite consumption.

(2) 45% Minimum Cr_2O_3, Minimum 2/1 Cr/Fe.

(3) 40% Cr_2O_3, Less than 2/1 Cr/Fe.

(4) 20% Minimum Al_2O_3, Refractory usage.

SOURCE: Study, Trends in the Usage of Chromium, National Research Council, Materials Advisory Board, Washington, May 1970, Publication NMAB-256.

TABLE 9

PRINCIPAL SOURCES AND APPLICATIONS OF CHROMITE IN U.S., 1967

GRADE OF ORE	AVERAGE % Cr_2O_3 IN ORE	ORE USAGE IN 1000 SHORT TONS	PRINCIPAL RESERVES OF ORE
Metallurgical	50.3%	818(1)	
	77% of net ore; Cr/Fe 3/1 -		Rhodesia, Russia, Turkey
	14% of net ore; Cr/Fe = 2/1 to 3/1 -		Rhodesia, Russia, Turkey, South Africa
	9% of net ore; Cr/Fe 2/1 -		South Africa
Chemical	45.2%	234(2)	South Africa, Rhodesia
Refractory	34.0%	340(3)	Phillippines

(1) Actual usage of 50.3% ore. Ferroalloys also used 42,000 tons of chemical grade and 30,000 tons of refractory grade. Direct melting used 13,000 tons of chemical grade. These make totals of all ores for metallurgical usage equal to 903,000 tons.

(2) Actual usage of 45.2% ore. Of this, 55,000 tons went to metallurgical uses, including 42,000 tons to ferroalloys and 13,000 tons to direct melt additions.

(3) Actual usage of 34.0% ore. Of this, 30,000 tons went into ferroalloys for metallurgical uses.

SOURCE: Study, Trends in the Usage of Chromium, National Research Council, Materials Advisory Board, Washington, May 1970, Publication NMAB-256.

technology. Resources are normally not as well defined and do not share the requirement of being economically recoverable under existing price and technological conditions. Thus, proven reserves are distinctly limited while resources ultimately can encompass the total quantity of an element found in the earth's crust. However, by their definition reserves are capable of expansion or contraction as either price or technology changes. Historically, the vast majority of such changes have favored an increase in the reserves of most minerals. For example, one estimate has indicated that world proven reserves of chromium have increased by 650% during the twenty years from 1950 to 1970.[7] This has occurred in spite of a United States price decrease of 45% during the period of 1950 to 1973.[8] While this exact condition is unlikely to be repeated, it is likely that the proven reserves of chromite ore will continue to increase for some time. This is so for several reasons. First, the price of chromite ore is likely to increase as continued demand approaches available supply. This will make it economically feasible to explore and develop deposits of lower grade ores which may then be profitably mined. Second, the distribution of mineral deposits tends to be such that as the average quality of a deposit declines, the tonnages of ore that are available increase substantially. Hense, as industries move to lower quality deposits, mineable at higher prices, sharply increasing tonnages of ore become available.[9] Third, technological developments may occur which will make it possible to extract what are presently uneconomically recoverable reserves. The implication of these conditions is that while presently unquantifiable, the proven reserves of chromite and other ores appear certain to increase as price increases and technological change occur.

Geopolitical Concerns

The geographic distribution of currently known reserves of chromite ore occur only on the Asian and African continents and in the Philippines Archipelago. There are no known economically recoverable reserves in the Western Hemisphere. The United States has potentially large reserves of low grade ores which are uneconomical to exploit under existing price and technological conditions, although they have been mined under past war-time conditions at artificially supported prices. The United States ceased domestic production of chromium under the artificially inflated prices of the Government Defense Production Act in 1961. Since that time, 100% of requirements of both chromite ores and intermediate ferrochrome metals have been obtained from foreign sources. This dependence makes the United States potentially vulnerable to geopolitical as well as economic constraints from the producing nations. The possibility of such constraints being used against the United States is enhanced by the very small number of nations which dominate the production of chromite ore and the fact that the Soviet Union, a major ideological and political rival, is also a major supplier of high grade chromite ore.

The United States imported an average of 1,191,000 short tons per year of all grades of chromite ore from 1968 through 1972. In 1973, five nations supplied approximately 87% of the chromite ore imported by the United States. They were the Union of South Africa (31%), the Soviet Union (21%), Rhodesia (13%), Turkey (11%), and the Philippines (11%).[10] These five nations have also supplied the majority of the chromite ore to the United States for the past decade, although the relative market share of some of these nations has shown wide variations for other than economic conditions. Other nations such as Japan, Finland and West Germany have also provided substantial imports of intermediate ferrochromes throughout this same period. However, these countries, like the United States, lack domestic reserves of chromite ores and are dependent on the five major ore producers for their essential raw materials. These conditions make it important that the United States maintain favorable political and economic relations with these ore producing nations both individually and as a group. For this reason it is appropriate to briefly review certain critical issues which have hindered United States' relations with these ore producing nations in the past.

Rhodesia. Rhodesia has a relatively advanced economy which depends to a large degree on its domestic policy of racial separatism for its continued economic well being. The United Nations imposed mandatory economic sanctions against Rhodesia in early 1967, following Rhodesia's unilateral declaration of independence from Britain in November 1965. These sanctions banned all major imports and exports from Rhodesia, except those for humanitarian purposes, in an attempt to force Rhodesia to abandon her policy of white supremacy. These sanctions effectively severed Rhodesia's commercial and financial contacts with most major trading partners, except South Africa, and severely weakened her economy. For example, in 1971, Rhodesia experienced a balance-of-payments deficit of $R18.6 million ($21.5 million), one of the largest ever recorded in the history of the territory.[11] The United States honored these sanctions from their imposition until 1972, when she resumed importation of minerals from Rhodesia including chromite ores and intermediate ferrochromes. This importation was accomplished unilaterally under the Byrd Amendment to the Military Procurement Act of 1971 and does not indicate any abatement of United States/Rhodesian problems arising from the racial supremacy issue. Rather, it reflects a purely economic adjustment in spite of the underlying racial problems. This solution is probably unstable in the long run and indicates that further disruptions of relations between the two nations, with possible adverse impact on mineral supplies, appears likely.

Republic of South Africa. South Africa has institutionalized a similar policy of racial separation or apartheid in its own territory and that of Namibia, formerly South West Africa. Like Rhodesia, this has led to a growing restriction of South Africa's international contacts, including those within the United Nations General Assembly. The 1974 session condemned the policy and practice of racial supremacy by South Africa and recommended universally applied economic sanctions as the only means of achieving a peaceful solution to the problem.[12] The United Nations failed to impose sanctions but continued the embargo of the sale and shipment of arms, ammunition, military vehicles and related equipment and materials which it had initially imposed in 1963. The United States fully supported this embargo while maintaining generally friendly political and economic relations with South Africa. Throughout this time, the South African economy has remained strong due to her excellent natural resource base which includes 65% of the annual world gold output, 70% of the world's platinum reserves, 60% of all diamonds, 75% of chromium reserves, and 30% of all proven deposits of uranium.[13]

A fundamental problem in relying on South Africa as a source of needed minerals is the long-run viability of its internal policy of apartheid or racial separatism. Increasing concern in this area is being expressed by both white and non-white South Africans. The territorial segregation of the population into black homelands or "Bantustans" is likely to result in further political and economic problems. Economically, white South Africa needs the black labor force and the Bantustans need the state's economic support. Politically, these homelands can be used as a platform for agitation and the expression of dissatisfaction with the role of blacks in South Africa's future.[14] Many international organizations, including the United Nations and the Organization for African Unity, have condemned South Africa for this policy. While some attempts have recently been made to establish racial policies more attuned to present day realities, few results have been attained and considerable growing dissatisfaction exists both internally and internationally.

Political turmoil or internal conflict could easily lead to significant problems in the mining industry which is highly dependent on the black labor force. An international conflict could have an even more significant and long lasting effect. Such a conflict is not wholly unlikely, particularly in view of the recent Communist inspired and Cuban supported war between Mozambique and Rhodesia. This type of movement could easily be turned against South Africa because of its policy of apartheid or its refusal to permit the independence of Namibia (South West Africa) as requested by the United Nations. A major conflict in South Africa would impact all industrialized nations that rely on the wide variety of minerals exported by South Africa. These problems might be caused by labor strife, destruction of plant facilities, disruption of transportation facilities or by a combination of these and many other factors. But, possibly the most serious long term impact of a major racial conflict would be the loss to South Africa of a significant portion of the technical and managerial expertise needed to maintain its relatively high level of industrialization.

Another result of these conditions might be an expansion of the mutual interdependence between Rhodesia and South Africa in economic and domestic matters to circumvent the United Nations' sanctions against Rhodesia.[15] Whatever the outcome, these appear to have largely been political and moralistic problems which have created short term disruptions in relations between South Africa and the remainder of the international community. While they are highly destablizing in the short run, they only moderately pose a threat to the continuing long run supply of chromite ore and ferrochromes to the United States.

The Soviet Union. The Soviet Union is clearly the second major producer of chromite ore and therefore a most important geopolitical concern of United States' mineral resource policies. Since 1917, Soviet foreign trade has been a State monopoly managed by the Ministry of Foreign Trade within the overall national economic plan.[16] As a State controlled enterprise, the Soviets have increased their share of the total chromite market to 30-35% by the 1965-1968 time frame with an output of 85% high grade metallurgical ore and 15% refractory grade ore.[17] These increases occurred at a time when the United States was observing economic sanctions against Rhodesia over her policy of racial separation. These sanctions created an artificial shortage of chromium in the non-Communist world and afforded the Soviet Union an opportunity for expansion of her share of the chromite market. It also permitted the Soviets to substantially increase the price of her chromium exports to the United States. For example, low carbon ferrochrome increased in price by 65% between January 1969 and January 1971, while the price of chrome silicone increased 56% from January 1969 to July 1970.[18] This price increase obviously occurred to take advantage of the existing artificial shortage of chromium in the non-Communist world, but may also have supported other Soviet objectives at that time. For example, it may have been used to build up the Soviet's reserves of hard currencies for use in subsequent trading actions with Western nations.

It is not the intention of this paper to discuss the ideological, political or economic differences that exist between the Soviet Union and the United States. These differences are significant and well beyond the scope of this paper, but suffice it to say that in today's world the Soviet Union is the primary ideological and political adversary of the United States. As such, the United States could easily be denied access to this source of supply on short notice for what could be prolonged periods of time. These disruptions in the flow of materials could be as a result of ideological or political confrontations well short of armed conflict. Although tensions between the Soviet Union and the United States have been lowered significantly in the past few years and economic activity between the two nations has risen, it would still be presumptuous today to consider the Soviet Union as a reliable source of minerals.

For example, an attempt by the Soviet Union to arbitrarily withhold chromite from the world markets is considered a possibility.[19] However, the likelihood of this occurring has severely diminished with the resumption of imports of chromite ore from Rhodesia and the continuing purchase of food grains from the United States by the Soviets. Recent technological improvements have also lessened the potential impact of any reduction in Soviet chromite production by making it possible to use lower quality chemical grade ores in certain metallurgical applications. Thus, while certain geopolitical constraints could theoretically be invoked by the Soviet Union, their impact on the United States chromium supplies would not have the disruptive effect that such actions would have had during the embargo against Rhodesian ores. Therefore, they will probably not be applied in the immediate future.

<u>Turkey</u>. Turkey has been a long time ally of the non-Communist world and is a founding member of the North Atlantic Treaty Organization. As such, she generally supported the United States and other Western powers until

the mid-1960's in an attempt to insure continued Turkish independence, particularly from the Soviet Union. Since that time, relations with the United States have cooled. The dominant reason for this change has been the question of Cyprus. In its simplest terms, Turkey has felt that the United States has not supported Turkish interests on Cyprus while in fact supporting the interests of Greece. These feelings were exacerbated by United States Congressional action which imposed a ban on military aid to Turkey on the grounds that the use of American equipment on Cyprus by Turkey violated United States' military aid laws. One other less significant issue has troubled United States-Turkish relations. That is the lifting of the ban on the cultivation of the opium poppy in July 1974. Neither of these issues has critically damaged relations between the two countries, primarily because of the continued Turkish desire for freedom from the Soviet Union. Therefore, neither appears likely to result in the long term loss of mineral imports from Turkey.

Philippines. The Philippines have traditionally held close alliances with the United States. They have supported the United States' actions in Viet Nam and have been strongly anti-Communist. In recent years, this support has diminished somewhat due to uncertainty about the United States' role in Southeast Asia after the war in Viet Nam and over the extensive United States' military rights in the Philippines. This concern has led the Philippines to seek a greater independence in foreign policy which included the establishment of diplomatic and trade relations with a number of Communist countries. These new interests appear to reflect the realities of a multi-polar world more than a condition likely to result in curtailment of trading relations with the United States. For these reasons, continued supplies of chromite and other commodities can probably be expected from the Philippines.

This brief review indicates that the United States has experienced several specific geopolitical problems with the principal suppliers of chromite ore during the relatively recent past. It also indicates that a collective problem has occurred with only two of these suppliers, Rhodesia and South Africa. This lack of unification as regards specific difficulties between the United States and the major supplying nations makes a meaningful, long-term denial of chromite ore unlikely under presently existing international conditions. There is, however, one possible exception to this conclusion which must be mentioned. That is the extremely unlikely occurrance of large scale armed hostilities where military intervention would be employed. Should this occur, the distant geographic location of all chromite ores and the necessity to transport them by waterborne carrier could present a severe limitation to imports. Many factors which are beyond the scope of this paper would affect the success of such a campaign. The purpose of this paper is to identify it as a possible constraint on ore supplies and suggest it as an area requiring additional study.

Cartels. Since the possibility of outright denial of chromite is considered highly unlikely, what about the possibility of cartel-like action to significantly increase the price of chromite? This too appears highly unlikely for several reasons. The most important being the character of the producing nations themselves, along with the nature of the product. The chromite market realistically consists of three distinct sub-markets, metallurgical, chemical and refractory, with little interchange among them until very recently. Concurrently, certain suppliers have dominated specific sub-markets, the Philippines producing a majority of refractory grade ores while South Africa dominated chemical grade production. The Soviet Union, Turkey and Rhodesia have supplied the majority of metallurgical grade ores. This initially appears to offer ideal conditions for a cartel-like action to substantially raise prices. However, this is not the case because of either market considerations or certain producer relationships. The most obvious market where cartelization is unlikely is the refractory. Here the steadily declining demand and transition to readily available new processes which do not use chromium would only be accelerated by a significant price rise. Many of the same conditions exist in the chemical grade markets. While the chemical grade market is slowly growing at present prices, there are adequate substitutes for most chemical grade uses. Also, these substitutes are available at only marginal increases in cost or decreases in performance. Therefore, significant long term substitution with a concurrent reduction in the chemical grade market is likely to occur if prices rise significantly. This leaves the most important sub-market for consideration, the metallurgical. Currently, over 60% of total chromium usage occurs in this market. Major producers are the Soviet Union, Rhodesia and Turkey. Also, the prospects of substitution in the major use of metallurgical grade ore, stainless steel production, is very low at present. Thus, from a market demand standpoint, cartel action can not be entirely ignored. Therefore, the producing nations must be examined to see if this is likely to occur. To do this, we must first emphasize one point. That is, a a cartel can successfully increase prices only if it restricts output. This implies an agreement among producers which "fixes" the total production of chromium at a level generally lower than would be the case without a cartel. For a number of reasons, such agreements have historically been extremely difficult to maintain. Among these are different production costs among cartel members, a strong incentive to cheat by individual members, and differences in economic structures and political philosophies among the producers.[20] These restraints appear throughout any comparison of the Soviet Union, Turkey and Rhodesia and would appear to make any cartel-like action most unlikely. The inclusion of South Africa, whose chemical grade ores are increasingly being used for metallurgical applications through new technology, would change the outlook somewhat. Rhodesia and South Africa have already adopted a largely unified political and economic approach because of their common racial policies. There is also evidence that Rhodesian ores are being refined into ferrochromes by South Africa. Thus, if the Soviet Union provided only tacit cooperation, as she has done in the diamond market, some level of cartel-like action to raise prices would be possible. Whether this will occur and the exact nature and magnitude of such an occurrance is another question which can not be answered at this time.

In summary, cartel action to significantly raise prices appears unlikely in either the refractory or chemical grade ores and appears as only a remote possibility in the metallurgical markets.

Substitution of Other Minerals

The possibility of substitution for chromium is almost exclusively dictated by the intended end use of the ore, whether metallurgical, chemical or refractory. This is in large measure due to the specific characteristics imparted by chromium on its end item products such as corrosion resistance in metallurgical uses or brilliant yellow hue in pigments. Within the metallurgical applications the possibility of substitution extends from virtually none for stainless steel production to a moderate potential, with some serious qualifications, for the other alloy steels. Chemical and refractory uses generally offer much better possibilities for substitution.

Metallurgical Grade. The major metallurgical use of chromium in the production of stainless steel produces highly desirable corrosion and oxidation resistant qualities in the finished product. This can not be duplicated by substitution since "stainless steel can not be produced without chromium".[21] In emergencies where adequate quantities of metallurgical grade chromite were not available to produce stainless steel, alternates such as cupronickel, ferritic steels and titanium alloys may be substituted for stainless steel with both cost and performance penalties. However, these potential substitutes are subject to serious scarcities themselves and are currently produced in very limited quantities equal to only about 5% of the output of stainless steel.[22] Thus, they fail to provide a suitable alternate to the use of stainless steels in current application. With these conditions in mind, it is accurate to conclude that chromium has no practical substitutes in the production of stainless steel and there are no practical alternates to the continued use of stainless steel in contemporary military and commercial applications.

The second major end item use of chromium is in the production of various alloy steels, including tool steels. This application offers a much improved potential for substitution for two significant reasons. First, the majority of the uses for alloy steels, excluding stainless steel, are in general, non-strategic applications in the transportation, general construction, automotive, and general purpose industrial categories. In these areas chromium alloys derive their utility from properties of hardness, response to heat treatment, and resistence to fatigue. These are significantly general physical properties which are found in several alternate alloys which do not contain chromium, for example nickel and molybdenum based steel alloys. These physical characteristics also exist to some degree in other elements such as aluminum, manganese, and boron. Therefore, substitution based on the physical properties of the chromium alloys is technically possible within the limits of available supplies of these alternate materials. Improved technology offers the second reason for an improved substitution potential for chromium in alloy steels, excluding stainless steel. Recently, new very low alloy carbon steels fortified with small non-strategic additions of boron have been formulated which offer greater possibilities for non-strategic substitution in the future.[23] Thus, substitution in non-strategic alloys based on certain physical properties of the end item appears to be both technically feasible and possible in a situation of national emergency where a slight cost or performance penalty would assume a lower relative priority.

Chemical Grade. The possibility of substitution throughout most industries which use chemical grade chromite ore is good to excellent. The wide variety of chromium derived salts used in wood and water treatment, textile dyes, leather tanning operations, and medical products can all be substituted with existing materials with only minimal reductions in effectiveness or cost increases. For example, sodium silicate is approximately 70% as effective as sodium bichromate in the manufacture of water treatment compounds for use in water cooling towers for refrigeration and air conditioning. The same general condition exists in the textile and leather industries where aluminum hydroxide and vegetable tans will substitute with either higher costs or diminished effectiveness. Two uses of chemical grade chromium would present problems of some magnitude if they were to be discontinued. These are in electroplating of hard chromium coatings to achieve a high abrasion resistance and in the production of oil well drilling muds. There are currently no substitutes for hard chromium electroplating and therefore, a higher wear rate would be inevitable if a shortage of chromium was encountered. A similar situation exists in the production of oil well drilling muds where ferrochrome lignosulfate contributes to the density and sealing characteristics of the drilling mud. Its absence could not curtail oil well drilling operations, but would make them more time consuming and costly.

Refractory Grade. The major proportion of refractory chromite is formed into bricks and used for furnace lining in the open hearth type of steel producing furnace. Use of the open hearth method of steel production is rapidly declining as newer electric furnaces gain widespread acceptability. In addition, magnesite can be substituted for chromite in certain of these refractory applications. For these reasons, substitution appears possible throughout most of the refractory uses of chromium although both cost and performance would be adversely affected.

Conclusion

The preceeding review clearly indicates that total substitution for chromium is presently impossible. Therefore, the United States must of necessity retain an adequate, reliable supply of certain grades of chromite ore. As we have seen, this objective is normally satisfied by importation which is subject to curtailment or limitation for military, political or economic reasons. Thus, some alternate means is required to meet this objective. This has historically been accomplished through the development of domestic production capabilities and through stockpiling. This report will briefly review the achievements of these methods and then suggest an area where future United States' action may be desirable.

Development of Domestic Sources. The United States has no reserves of high grade chromite ore which are economically recoverable under current market conditions. The last domestic production of chromite occured from mines in Montana in 1961 under the Government Defense Production Act. This Act artificially inflated the price paid domestic producers of chromite ores to over $110/ton as a means of encouraging domestic production and lessening foreign dependence. This price is far above the $45/ton paid for higher quality South African chemical grade ores in 1975 and demonstrates the improbability of future domestic production.

Stockpiling. Chromium has been designated a strategic material and is currently maintained in the national stockpile. The quantities, types and value of chromium in the stockpile as of 30 November 1975 were as shown in Table 10. The established objective represents the shortfall between estimated available supply and estimated requirements for the first year of a conventional war fought simultaneously in Europe and Southeast Asia. The present inventories exceed objectives to a significant degree because of a recent change from a three to a one year objective supply.

The success of the present stockpile program is evident. However, questions of the utility of a stockpile to any future conflict which may involve nuclear

TABLE 10

STOCKPILE STATUS OF CHROMIUM AS OF 11/30/75

(1,000 Short Tons)

MATERIAL	OBJECTIVE	TOTAL INVENTORY	TOTAL EXCESS	AVAILABLE FOR DISPOSAL	SALES 11 MONTHS
CHROMITE:					
Metallurgical Grade	445	1,953	1,508	0	0
Chemical Grade	8	250	242	0	0
Refractory Grade	54	400	346	0	0
CHROMIUM FERROALLOYS	11	757	746	0	0
CHROMIUM METAL	---	4	4	0	0

NOTE: In addition to the data shown, the stockpile contains the following nonstockpile grade material: 551, 758 tons of metallurgical grade chromite and 23,764 tons of chromium ferroalloys.

SOURCE: Commodity Data Summaries, 1976, p. 34.

weapons and of the cost of materials storage have frequently been raised. These objections may result in further reductions in both objective quantities and on-hand inventories which could severely limit the utility of the stockpile in times of national emergency. Such a possibility reemphasized the necessity of dependable, adequate foreign sources of mineral resources in the future.

Future Actions. The United States will remain dependent on foreign sources for an adequate, long-range supply of chromium. This dependence requires the United States to use all methods necessary to guarantee itself access to suitable supplies of either chromite ores or intermediate ferrochromes. The authors feel this objective can be met if the United States exploits certain inherent advantages which she has. One such advantage is an existing and projected dominance as a producer of agricultural commodities and foods which will afford increasing leverage as world population continues to increase. The exact method of using this potential leverage will vary with the situation and is presently far less important than an early realization that it exists.

CHAPTER IV

COBALT

Introduction

Cobalt is a hard silver-grey metal in its pure state. It closely resembles both iron and nickel in hardness, strength and other properties. Cobalt is widely used in the aircraft and electronics industries in which a disruption in the supply would have a severe impact on capabilities.

In reviewing the problems of assuring an adequate and uninterrupted source of cobalt this study will first examine the commercial and military uses of cobalt and then examine the expected demand for this element in the years to come. The sources of cobalt will then be examined and the resulting geopolitical problems will be discussed. The study will next review and evaluate the actions taken to date to alleviate potential problems in the supply of cobalt. Some suggestions as to future dirrections of United States' policies and actions will conclude this portion of the study.

Uses of Cobalt

Until 1920 cobalt was primarily used in its salt form as a blue coloring agent in the glass and ceramics industries. Since then, cobalt has been increasingly used in its metallic state as an alloy. About 70% to 80% of the world production is now used in alloys where a high resistance to heat or high magnetic qualities are needed. Although an important alloy for steel, a relatively small amount of the metal is used when compared to other minerals.

The total United States' consumption of cobalt in 1973 was only 18,741,000 pounds.[1] Table 11 depicts the use of cobalt within the United States during 1972 and 1973. The primary uses of metallic cobalt are for superalloys and magnetic alloys. Cobalt salts, particularly organic salts, are used as driers for paints, varnishes, and inks. Illustration 1 depicts the trends in the primary uses of cobalt for the past twenty years. As can be seen, the uses of magnetic and superalloys has dropped while other metallic uses have risen.

Superalloys represent about 20% of the demand for cobalt within the United States. These alloys retain their strength and other properties at extremely high temperatures. Superalloys containing from 5 to 65 percent cobalt are widely used in the manufacturing of jet engines, gas turbines and other similar applications where resistenace to high temperature is essential.

TABLE 11

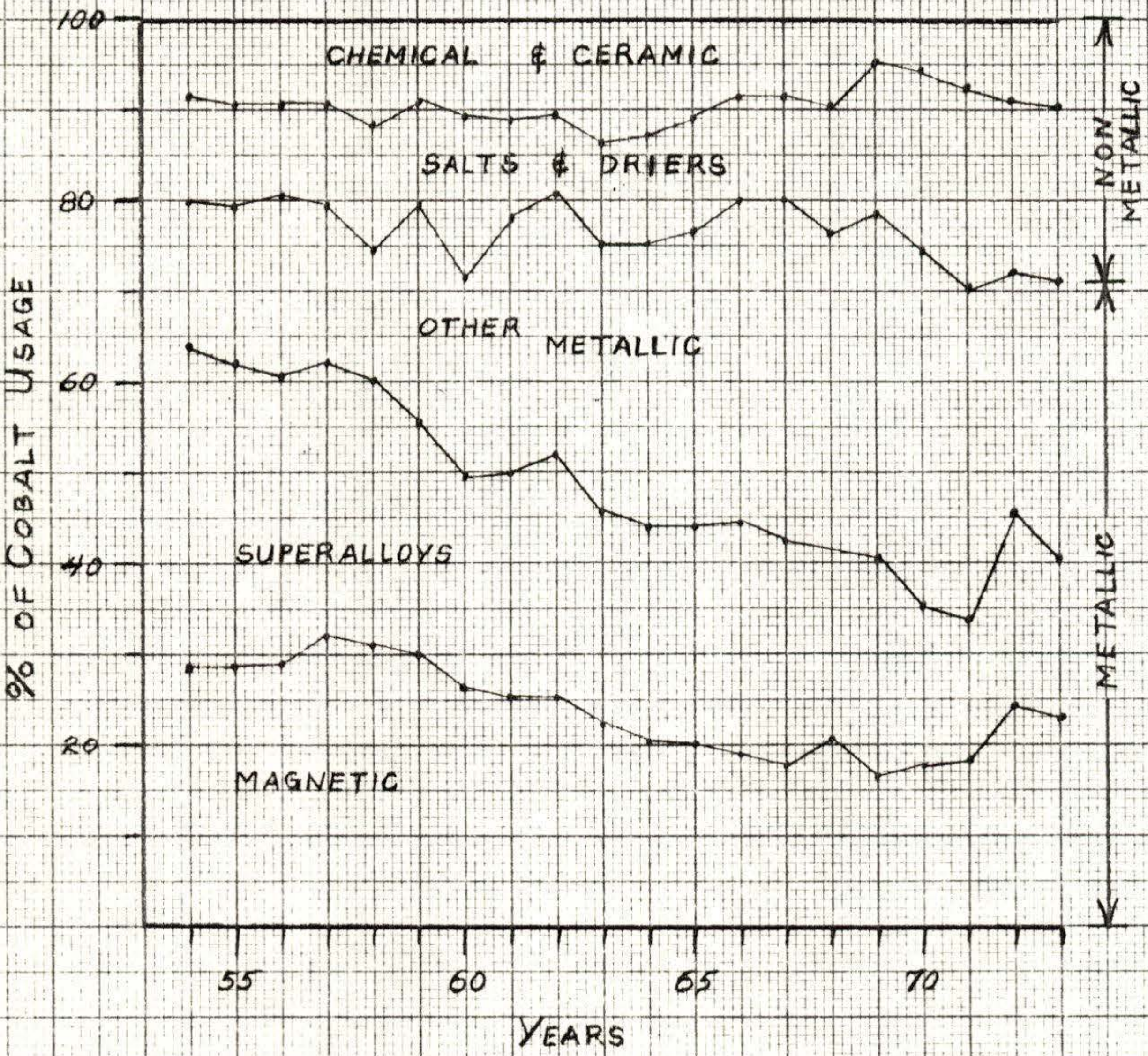
U.S. CONSUMPTION OF COBALT - 1972-1973

	1972		1973	
	Thousand Pound	%	Thousand Pound	%
Steel Alloys:				
Carbon	3	0.0	2	0.0
Stainless & Heat Resisting	39	0.3	32	0.2
Full Alloy	217	1.5	226	1.2
High Strength-Low Alloy	7	0.0	45	0.2
Electric	W		W	
Tool	361	2.6	518	2.8
Cast Iron	W		W	
Superalloys	3,012	21.3	3,282	17.5
Alloys (Other than Steel or Super):				
Cutting/Wear Resistant	1,273	9.0	2,511	13.4
Welding & Alloy Hand Facing Rods	199	1.4	391	2.1
Magnetic	3,441	24.4	4,302	23.0
Nonferroys	651	4.6	789	4.2
Other Alloys	676	4.8	755	4.0
Mill Products from Powder	W		W	
Chemical and Ceramic:				
Pigments	165	1.2	217	1.2
Catalysts	702	5.0	1,150	6.1
Ground Coat Frit	144	1.0	165	0.9
Glass Decolorizer	61	0.4	64	0.3
Other	173	1.2	197	1.1
Salts & Dryers:				
Lacquers, paints, feed, etc:	2,691(e)	19.0	3,569	19.0
Miscellaneous	315	2.2	526	2.8
TOTAL	14,130	100.0	18,741	100.0%

e - Estimated
W - Withheld to avoid disclosing company confidential data; totals included in Miscellaneous.

SOURCE: U.S. Bureau of Mines, Mineral Yearbook, Volume 1 Metals, Minerals and Fuels, 1972 & 1973

PRIMARY USES OF COBALT 1954 TO 1973



SOURCE: VARIOUS ISSUES MINERAL YEARBOOK

Magnetic alloys account for about 25% of the United States' demand for cobalt. Cobalt is an essential element in the high quality permanent magnets used in electronic and communications equipment.

Cobalt has a wide variety of uses which consume somewhat smaller percentages of the element. It is used as a binder to produce durable tungsten carbide machine tools and drill bits. Cobalt-60, a radioisotope form of the element, has both industrial and medical uses. In this radioactive form, cobalt has been used in the treatment of cancer.

Cobalt is of significant importance to the maintenance of a modern military. Cobalt alloys are important components of jet engines, rocket engines, and gas turbines. Magnetic alloys are likewise very important in defense production. They are used in various forms of electronics equipment, communications equipment and aircraft and missile guidance systems.

Research by the Stanford Research Institute indicates that in 1963 26% of the cobalt used in the United States was devoted to military purposes. The military demand has been decreasing in terms of the overall United States' demand, and in 1972, defense purpose amounted to only 12% of total demand.[2] The relationship of the defense sector's demand to total United States demand over the ten year period from 1963 through 1972 is shown in Table 12. The annual fluctuations in percent of defense use is largely attributable to fluctuations in the overall United States' consumption, rather than to changes in defense requirements.[3]

Two general categories of use consumed over 80% of the cobalt used within the defense sector in 1972. The manufacture of aircraft or spacecraft engine parts consumed 62% of the cobalt used for defense purposes. Another 21% was used in various items of electrical equipment and supplies. The remaining 17% was used in several different items including airframe parts, paint and chemical products.[4]

Sources of Cobalt

The domestic mining of cobalt ores was discontinued in 1971. Thus, all cobalt consumed in the United States, other than recycled scraps, must be imported. Recycled scrap provides only a small portion of the annual United States cobalt requirements. During the period 1969 through 1973, purchased scrap never provided more than 2.4% of the United States' needs.

During 1973, the cobalt metal consumed in the United States was imported from fourteen nations. (Table 13) Zaire has been the primary supplier having provided 61%

TABLE 12

U.S. DEMAND FOR COBALT USED FOR DEFENSE PURPOSES

YEAR	PERCENT
1963	27
1964	24
1965	17
1966	19
1967	22
1968	23
1969	16
1970	17
1971	17
1972	12

Ten Year Mean in Defense Use - 19.4

SOURCE: Stanford Research Institute, p. 208.

TABLE 13

U.S. IMPORTS OF COBALT METAL BY COUNTRY
(Thousands of Pound)

	1971		1972		1973	
	Pounds	%	Pounds	%	Pounds	%
Austria	---	---	---	---	5	0.0
Benelux	2499	24.1	3344	25.6	4209	22.9
Canada	909	8.8	633	4.8	502	2.7
Dominican Rep.	---	---	---	---	23	0.1
Finland	1208	11.6	1299	9.9	909	5.0
France	126	1.2	500	3.8	197	1.1
Germany, West	2	0.0	12	0.1	39	0.2
Italy	---	---	---	---	45	0.2
Japan	---	---	45	0.3	5	0.0
Netherlands	42	0.4	49	0.4	16	0.1
Norway	800	7.7	915	7.0	972	5.3
Taiwan	---	---	---	---	55	0.3
United Kingdom	223	2.1	131	1.0	187	1.0
Zaire	4572	44.0	5083	38.9	11196	61.0
Zambia	---	---	1071	8.2	---	---
TOTAL	10381	100.0	13082	100.0	18360	100.0

SOURCE: U.S. Bureau of Mines, Minerals Yearbook, Volume 1, 1973, p. 406

U.S. Bureau of Mines, Minerals Yearbook, Volume 1, 1972, p. 422

of the cobalt metals needs in 1973. Other important sources of cobalt have been Belgium-Luxembourg, Finland, Norway and Canada. However, only five of the nations supplying the United States with cobalt in 1973 actually mined ores containing cobalt. The other nine nations had processing or recycling capabilities, but relied on other nations for their source of ores or scrap.

A better overall picture of the primary sources of cobalt can be obtained from examining the world mine output. The world production of cobalt by country from 1971 through 1973 is displayed in Table 14. Zaire is the leading producer of cobalt ores in the world, and has produced well over one half of the world's supply for the past several years. Together with the neighboring country of Zambia, these two countries produce about two-thirds of the world's output of cobalt rich ores. Canada and Cuba are the only two western hemisphere nations producing cobalt ores. Together these two countries represent about 13% of the world's production.

Future Demand

The consumption of cobalt can be expected to expand in the future, as the requirements for high performance jet and gas turbine engines and complex-electronics components increase. After some years of decline, the

TABLE 14

WORLD MINE OUTPUT OF COBALT BY COUNTRY
(Short Tons)

	1971		1972		1973	
	Tons	%	Tons	%	Tons	%
Australia	877	3.2	830	3.2	840	3.0
Canada	2161	7.9	1676	6.5	1973	7.0
Cuba (e)	1700	6.2	1700	6.6	1800	6.4
Finland (e)	1400	5.1	1400	5.4	1400	5.0
Morocco	1078	3.9	1766	6.8	1567	5.5
Norway	N/A	---	N/A	---	N/A	---
USSR (e)	1750	6.4	1800	6.9	1850	6.5
Zaire	16003	58.6	14453	55.7	16625	58.8
Zambia (e)	2330	8.5	2300	8.9	2200	7.8
TOTAL	27299	100.0	25925	100.0	28255	100.0

N/A - Not Available
(e) - Estimate

SOURCE: U.S. Bureau of Mines, <u>Mineral Yearbook</u>, Volume 1, 1973, p. 410

United States' demand for cobalt rose in 1972, and a 33% further increase in consumption in 1973 continued this upward trend. This increased consumption was a direct result of a rise in industrial activity within the United States.[6] The Stanford Research Institute Study, based on an analysis of the demand situations surrounding the use of cobalt, has projected a steady increase in the United States' demand for cobalt through the year 2000. Their model forecasts the United States' demand for cobalt as being 20,000,000 pounds in 1985 and 26,000,000 pounds by 2000.

As the underdeveloped and lesser developed countries become more industrialized, the international demand for cobalt can also be expected to increase. However, the authors have found no projections of the prospective international demand for cobalt through the remainder of this century.

Although future world demand is difficult to estimate, current reserves of cobalt appear ample for the foreseeable future. Known world wide reserves of cobalt ores have been estimated as containing 3,000,000 tons of cobalt.[7] Based on the current rates of extraction (Table 14), these reserves would last over 100 years. Furthermore, about 200,000 tons of these known reserves are within the United States, although they are not currently being extracted.[8] Estimated world resources of cobalt are in excess of 4,000,000 tons of which over 800,000 tons are believed to be located within the United States.[9] Additional resources might exist in manganese nodules recently discovered on the sea floor. These could lead to millions of additional tons of resources.

New economical sources of cobalt have been discovered in recent years. Zaire in 1973 announced the discovery of two major new deposits containing an estimated 685,000 tons of cobalt metal. Recent discoveries in the Philippines promises to produce about 650 tons of cobalt metal a year.[10] In short, unlike other resources, there seems to be little likelihood that the world would "run out" of cobalt within the next hundred years. Known and likely sources appear ample for future needs.

Geopolitical Concerns

Although supplies of cobalt appear to be sufficient, access to these sources of supply could be interrupted, and thereby disrupt the flow of cobalt needed to sustain either or both the civilian and military requirements for the metal. Serious interruptions would most likely result from being denied the raw material by supplying nations, or the obstruction of transportation systems by a third power. Both aspects of the security of sources will be reviewed as they pertain to cobalt.

The attitudes of principle raw material suppliers to the United States must be examined closely to determine the security of these sources. The supplier nations today are sovereign nations. They are no longer the pawns of industrial powers. Many of these nations are developing, third world, countries that are nationalistic, idealistic and at times unpredictable.

Our most serious problems in obtaining cobalt could result if relations with Zaire were to deteriorate. Zaire is easily our principal cobalt supplier having supplied directly 44%, 40%, and 61% of the United States' consumption in 1971, 1972, and 1973 respectively. In addition, Zaire provides the cobalt ore to nations that export metallic cobalt to the United States. As a result, our dependence on cobalt from Zaire is even greater than that indicated by direct imports. The Stanford Research Institute estimates that in 1972, 47% of the United States' demand was actually satisfied by cobalt originating in Zaire.[11] A similar figure for 1973 might be from 65% to 70% of the United States' demand based on the high percentage that was supplied by direct imports from Zaire. The Bureau of Mines estimates that 83% of the United States' 1974 cobalt imports will originate in Zaire.[12] With the recent large deposits found in Zaire, that country will continue to be the prime source of cobalt in the foreseeable future.

Zaire follows a generally moderate line of foreign policy, but some evidence of a rise in nationalistic tendencies exists. In 1967, they nationalized the country's largest mining company and later the "Return to Authenticity" program was established. The authenticity movement is an attempt at unification of the once disorganized tribal factions that were prevalent in the colonial and early post-colonial days. The program has changed the name of the country to Zaire and given original Zairian names to citizens and governmental organizations.[13] Although occasionally hampered by economic ties with Western Europe and the United States, during the past ten years Zaire has made substantial economic gains.[14]

Two important current issues might affect the availability of cobalt and other minerals obtained from Zaire. The first of these is the current economic stability of Zaire. The largest contributor to that country's export earnings is the copper industry. Zaire produces about 10% of the world mine output of copper. Because of the relatively high copper prices in the early 1970's, the government greatly expanded its economic development programs. However, with copper prices currently about half their previous levels, Zaire is having difficulty repaying loans and is threatened with bankruptcy. These financial problems, if not promptly resolved, could result in domestic turmoil and thereby disrupt the flow of many minerals, including cobalt, from this resource rich country. The United States has in the past and is likely to continue to provide Zaire with some economic aid. While this aid is of significant help, a general rise in the price of copper is needed to return Zaire's economy to a strong position.

A second issue of considerable concern to Zaire is the neighboring country of Angola. Zaire depends on the Benguela Railroad for the shipment of copper and cobalt from its Shaba (Katanga) region through Angola to the part of Labito on the Atlantic Ocean. There has been considerable fighting along this railway between opposing factions in the Angolan civil war. Most railway managers and technicians have abandoned their jobs, and the railway has ceased to operate. As a result, Zaire has been shipping ores by slower and more expensive routes, which can not handle the quantity of shipments formerly carried on the Benguela Railway. Economic considerations have also played an important role in Zaire's active opposition to the Communist backed Popular Movement for the Liberation of Angola (MPLA) regime in Angola. Zaire believes that an MPLA regime in Angola would allow the

Soviet Union to effectively control Zaire's shipments through the port at Lobito, and that such economic controls by the Soviet Union would be unacceptable. Zaire also feels that the Soviet Union is actively supporting rebel movements in Zaire's eastern regions. As a result, Zaire has been actively resisting the growth of Soviet influence on its political and economic affairs.[15] The Angolan civil war is currently affecting the flow of many minerals, including cobalt, and a resolution of this war in favor of the MPLA might further restrict the availability of these minerals to industrial nations. Even if the Angolan question were resolved in favor of Zaire's interest, the financial problem might be aggravated. Both Zambia and Zaire have been stockpiling large portions of their copper production during the Angolan strife, and the release of these stockpiles would likely restrict copper prices from rising above their current depressed levels.

The second largest supplier of the United States' demand is Belgium and Luxembourg. Together their shipments have satisfied 24%, 26%, and 23% of the United States' demand during 1971, 1972, and 1973 respectively. However, this source must itself import the basic raw materials, since neither nation possess cobalt ore deposits. Most of these ores come from Zaire. For this reason, many of the same limits that apply to the importation of Zaireian ore also apply to the import of metallic cobalt from Belgium and Luxembourg.

Norway, Finland and Canada are our next most important sources of supply, but their importance has been dwindling for the past several years and in 1973 they combined to supply only 13% of the United States' demand directly. However, Canada does export a large percentage of her cobalt to Europe for further refining, and much of this metal is then exported to the United States. The Stanford Research Institute estimated that in 1972 Canadian ores actually supplied 9% of the United States' demand.[16] This is almost double the amount imported directly from Canada.

The relatively small amounts of cobalt imported from sources other than Zaire, preclude these countries from individually disrupting the flow of cobalt imports to any significant degree. To significantly impact the price or quantity of United States' imports, these nations would have to join with Zaire in a cartel similar to the Organization of Petroleum Exporting Countries (OPEC). However, the economic importance of cobalt is relatively low in each exporting country, and significant political, cultural, and economic differences exist among the cobalt exporting countries. Thus, the formation of any effective cartel to control the price or production of cobalt is unlikely. Further, with the exception of Zaire, no nation or group of nations could significantly affect the United States import of cobalt by refusing to sell the mineral to United States' customers.

The only manner in which the import of cobalt could effectively be disrupted by a nation, other than Zaire, is by obstruction of the transportation system. One such disruption, that of the Benguela Railway in Angola, has been previously discussed.

Both Zambia and Zaire are now exporting much of their mineral outputs on the Tanzams Railway between Zambia and the Tanzania port of Dar es-Salaam, and by railway through Rhodesia. However, because of difficulties between Zambia and Rhodesia, the Rhodesian route, although used to some extent, has been officially closed. These long rail routes terminate at overcrowded ports and are susceptable to being closed for political reasons.

The sea lines of communication present potentially the greatest opportunity for disrupting the flow of cobalt between Zaire and western industrial nations. During past wars, sea routes in general have been particularly vulnerable to enemy action, and this would likely be the case in future conventional conflicts. All imports to the United States, except for those from

Canada, would be susceptable to interdiction of sea routes. As indicated in Table 13, 96.8% of the United States 1973 imports of cobalt and 94.9% of 1972 imports, were transported across the Atlantic Ocean. Thus, the Atlantic sea routes during periods of armed conflict would present a particularly vulnerable area for disrupting needed mineral shipments and thereby significantly impact the United States' industrial base if the conflict were broad and protracted.

Substitution

Cobalt is closely related to nickel and some substitution of cobalt-saving combinations in magnetic alloys or cemented carbide tools may be possible. However, cobalt has electromagnetic properties which are superior to nickel, and its heat and wear resistance properties make cobalt superalloys and tooling particularly desirable. These three areas include the largest and most strategic uses of cobalt metal, and substitution of significant quantities of cobalt in these alloys would be difficult. The economics of the particular application would be the driving factor to any substitutions. Since adequate supplies of cobalt are available at reasonable prices little effort has been directed to the development of various substitutions which might directly or indirectly save cobalt. Changes in the price and availability of cobalt would be required before an active effort to develop substitutions for cobalt metal were initiated.

Stockpiling

Cobalt has been designated as a strategic material. As such, stockpiles of the metal are maintained by the Federal Preparedness Agency in order to decrease and prevent the dangerous and costly dependence of the United States upon foreign sources of cobalt during periods of national emergency.

As of 30 June 1975, the national stockpile of cobalt contained 48,920,040 pounds valued at $195,700,000. The Federal Preparedness Agency has established an objective to maintain 11,945,000 pounds of cobalt in the national stockpile.[17] The objective is based on high priority requirements for cobalt metal during the first year of a major conventional war. Adjustments in the objective have been made to allow for the substitution of other metals for cobalt during the period of emergency.

The Federal Preparedness Agency is reducing its inventory levels of cobalt to meet its objective inventory level. Between July 1974 and June 1975, about 6,000,000 pounds of cobalt were sold for industrial use.[18] Current legislation allows for the disposal of cobalt inventories to a level of 38,200,000 pounds. Additional disposal legislation would be required if the Federal Preparedness Agency's stockpile objectives are to be met.

Development of Domestic Sources

No domestic cobalt ores of high quality have been found and there has been no domestically mined cobalt since the end of 1971. Efforts have been made to develop mines in Idaho since that time, but no output has been produced.[19] When domestic sources were producing, the cobalt was a by product of the mining of zinc or iron. However, even as a by product, domestic cobalt production can not compete with the price of cobalt from foreign sources. Increases in the price of cobalt, or severe reductions in its availability on international markets would be required before domestic cobalt production could be profitably resumed. The specific requirements for this occurrence were detailed in the previous chapter on chromium and do not require repeating.

Conclusions

In ranking 74 strategic materials as to their potential for adversely influencing the national security, the Stanford Research Institute rated cobalt as the eleventh most severe problem.[20] Three factors contributed significantly to this high ranking; the high percentage of the United States' demand used within the defense industries, the high percentage of imports, and the difficulty in substituting other materials for cobalt. While this may be a high ranking, the problem is not as severe as this study implies.

From our review it is apparent that on a world wide basis there is no shortage of cobalt. Ample reserves exist, and many of these reserves, although of lower quality ores, exist within the United States and Canada. These sources could be developed in case of a national emergency.

The national stockpile objectives seem sufficient to assure the continued support of defense requirements and other high priority uses during the time it would take to develop domestic sources of cobalt. During this period of emergency, lower priority uses of cobalt would have to use substitutes, be curtailed or be supported only to the extent that imports could be continued.

Although planning and controls on the consumption of cobalt would be required in the event of a conventional war, priority needs for cobalt metal could be met. Current planning in this area appears to be adequate to meet the United States' security requirements during a protracted conflict based on current and projected trends in cobalt consumption.

A problem might result, if for reasons other than armed conflict, sources of cobalt were denied the United States' economy. The only likely manner in which this would occur is because of diplomatic difficulties with Zaire. Under these circumstances, the Federal Preparedness Agency would be reluctant to lower the strategic stockpile level below the current objective. Thus, domestic shortages of cobalt would result that could impact the United States' economy as a whole. This impact would not be nearly as severe as that experienced during the oil embargo in 1973. To preclude this type of problem, our relations with Zaire must remain stable, and should encourage increased economic activity between United States' industry and Zaire. Although cobalt is but one relatively small issue in the ultimate determination of United States' relations with Zaire, it typifies the need for strong relations with this resource rich nation. Continued economic aid to Zaire would help to strengthen her economy which is currently in a very weakened position. Here again, continuation of our current foreign and economic policies towards Zaire would appear in order.

As stated at the beginning of this paper, a modern industrialized nation needs dependable sources of its strategic minerals. Cobalt is no exception. However, a long term disruption in the flow of cobalt from foreign sources, whether because of political, economic, or military action, would have little impact on the United States' economy or its national security.

CHAPTER V

PLATINUM GROUP METALS

Introduction

The platinum group of metals includes platinum, palladium, iridium, osmium, rhodium and rutherium. These elements are located throughout the world, but usually in small amounts that preclude their economic extraction. The platinum group in their metallic state are silver-white and ductile.

Platinum and palladium are used by United States industry to a much larger extent than the other four metals in the grouping. In fact, platinum and palladium have consistently amounted to about 95% of the consumption of platinum group metals by weight. This relationship is shown in Figure 15. These two elements can be analyzed and further segregated so as to determine the fraction of the total United States' demand for each that is derived from the defense sector of the economy. Thus, this report will be primarily concerned with these two members of the platinum group and their potential problems.

In reviewing the problems of assuring adequate and uninterrupted sources of platinum group metals this study

TABLE 15

PLATINUM-GROUP METAL DOMESTIC CONSUMPTION
1954 - 1972
(100 Troy Ounces)

	PLATINUM	%	PALLADIUM	%	OTHER METALS	TOTAL
1972	543	34.8	876	56.2	141	1560
1971	431	34.0	760	60.0	75	1266
1970	475	36.6	739	57.0	83	1297
1969	532	38.7	759	55.3	82	1373
1968	496	38.6	721	56.2	67	1284
1967	634	47.5	621	46.5	79	1334
1966	691	41.2	894	53.3	91	1676
1965	411	34.6	717	60.4	59	1187
1964	451	40.3	591	52.9	76	1118
1963	424	42.3	527	52.5	52	1003
1962	304	35.1	520	60.0	42	866
1961	283	34.4	508	61.7	32	823
1960	324	41.8	414	53.4	37	775
1959	363	40.5	488	54.5	45	896
1958	264	38.3	395	57.2	31	690
1957	348	46.6	367	49.2	31	746
1956	431	50.2	400	46.6	28	859
1955	467	54.9	352	41.4	32	851
1954	320	55.0	235	40.4	27	582

SOURCE: U.S. Bureau of Mines, Minerals Yearbook, Volume 1, Various Issues will first examine the commercial and military uses of these metals and then examine their expected demand until the year 2000. The study will also review the sources of these metals and discuss significant geopolitical concerns which could affect the availability of these metals. Some of the actions taken by the United States Government to alleviate the potential problems in the supply of platinum and palladium will be reviewed and evaluated. This portion of the study will conclude with suggestions as to possible future directions of United States' actions and policies concerning these metals.

Uses of Platinum Group

These metals are relatively inert, resist corrosion, and serve as excellent catalysts in many chemical processes. As such, the chemical industry is an extremely large user of platinum group metals. The electrical and petroleum industries are also very large users of platinum and palladium.

Within the chemical industry the platinum metals are used for several purposes. For example, platinum is a necessary catalyst in the manufacturing of nitric acid and fertilizers. Again acting as a catalyst, platinum, when combined with aluminum oxide, increases the octane rating of gasoline. Also, because of the general inert qualities of platinum, it is also an essential component of chemical laboratory and plant equipment. Palladium readily absorbs hydrogen and when heated it readily releases this hydrogen. Thus it is an important component in the refining of hydrogen.

The largest single user of palladium is the electrical industry. Palladium alloy contacts are used in equipment when low levels of electrical current are prevalent. Telecommunications equipment uses many palladium contacts. When combined with silver or gold, palladium is used in various thermocouples. Likewise, some platinum is used for electrical contacts and high temperature thermocouples or thermometers. When platinum is combined in a cobalt alloy excellent permanent magnets result. Palladium currently is displacing the more expensive gold and platinum in many of their electrical uses.

Within the area of medicine, both platinum and palladium are widely used. Platinum alloys are extensively used in the manufacture of surgical tools and palladium is used in dental alloys to improve strength.

The platinum group metals are not used in large quantities by industry, but they have a disproportionately large effect on the economy as a whole. The direct effects of platinum metals on the United States' economy might best be exemplified by the impact of platinum and palladium alloys in the electrical and electronic industries. However, this group of metals has an even more significant indirect impact on United States economic activity. The various acids and chemicals produced by processes utilizing platinum metals as catalysts are essential in the manufacturing of many other chemicals and goods which are fundamental to the maintenance of a stable economy.

The United States' annual consumption of the platinum group metals has been between 1,350,000 and 1,800,000 troy ounces from the late 1960's through 1973. In 1974 consumption jumped to 1,981,000 troy ounces and then as the economy slowed, 1975 consumption dropped to an estimated 1,300,000 troy ounces.[1] Recent palladium consumption has been more than 800,000 troy ounces annually while the annual consumption of platinum has been about 550,000 troy ounces. Tables 16 and 17 depict the industrial uses of platinum and palladium within the United States during the years of 1971 and 1972.

The metals within the platinum group are increasingly important to the maintenance of a modern military establishment. Important military uses of platinum metals alloys include magnets for wave tubes, telecommunications contacts, and electrical instrumentation curcuits. The

TABLE 16

U.S. CONSUMPTION OF PLATINUM
BY INDUSTRIAL TYPE

	1971		1972	
	1000 Troy Ounces	%	1000 Troy Ounces	%
Chemical	135	31.2	226	41.7
Petroleum	142	32.9	96	17.7
Glass	41	9.5	27	5.0
Electrical	52	12.0	92	17.0
Medical	23	5.3	30	5.5
Jewelry	19	4.4	21	3.9
Miscellaneous	20	4.6	50	9.2
	432	100.0	542	100.0

SOURCE: U.S. Bureau of Mines, Minerals Yearbook, Volume 1, 1972. p. 1046

TABLE 17

U.S. CONSUMPTION OF PALLADIUM
BY INDUSTRIAL TYPES

	1971		1972	
	1000 Troy Ounces	%	1000 Troy Ounces	%
Chemical	219	28.8	293	33.4
Petroleum	3	0.4	15	1.7
Glass	0	0.0	2	0.2
Electrical	432	56.8	425	48.5
Medical	62	8.1	94	10.7
Jewelry	19	2.5	19	2.2
Miscellaneous	26	3.4	28	3.2
	761	100.0	876	100.0

SOURCE: U.S. Bureau of Mines, Minerals Yearbook, Volume 1, 1971
U.S. Bureau of Mines, Minerals Yearbook, Volume 1, 1972. p. 1046

nitric acid produced by using platinum as a catalyst, is an essential ingredient in the manufacture of explosives.

The Stanford Research Institute study, quoted in previous chapters, indicates that during the period studied (1968 to 1972), between five and seven percent of the United States' consumption of platinum was expended within the defense sector of the economy. Likewise, between five and eight percent of the total United States' palladium consumption was devoted to military purposes.[2] The recent trends in consumption of both metals for military purposes has been decreasing in terms of quantities used and as a percentage of the overall United States' consumption. Recent consumption of these metals for defense purposes is shown in Table 18.

Four general categories of use accounted for about 84% of the platinum used within the defense sector in 1972. Telecommunications controls consumed about 31% of the platinum used for defense purposes. Another 25% was used in the refining of various petroleum products. Inorganic industrial chemicals represented about 17% of the defense demand, and organic industrial chemicals amounted to another 11%. The remaining 16% of the defense demand for platinum was used in a wide variety of items.[3]

Telecommunications controls used 56% of the palladium devoted to military purposes. Organic industrial

TABLE 18

U.S. DEMAND FOR PLATINUM GROUP
USED FOR DEFENSE PURPOSES

	PLATINUM		PALLADIUM	
	Troy Ounces	% of U.S. Demand	Troy Ounces	% of U.S. Demand
1968	34,730	7	57,720	8
1969	37,220	7	53,110	7
1970	33,225	7	51,755	7
1971	25,865	6	38,005	5
1972	27,145	5	43,800	5

SOURCE: Stanford Research Institute Study, p. 209

chemicals represented another 21% of the military demand for palladium. Inorganic chemicals amounted to 5% of the defense demand. The remaining 18% of the defense demand for palladium was used in various items, including about 2% for petroleum products.[4]

Sources of Platinum Group

One company mines a small amount of platinum group metals in Alaska, and virtually all of the remaining United States' primary production is as a by-product from the refining of copper. The refining of secondary metal, or scrap reprocessing, produces a considerably larger, but still relatively small, percentage of the total United States' demand. Table 19 relates the domestic production, both primary and secondary, of all platinum group metals to the total United States' consumption for the years 1971 through 1975.

Exports of refined platinum group metals have consistently been over twice the domestic production of these metals, since some imported metals are reexported after processing. Thus imports of these minerals have essentially accounted for 100% of the total United States' requirements. A detailed analysis of the imports for consumption of platinum group metals for 1971 and 1972 is presented in Tables 20 and 21. As can be seen, the

TABLE 19

DOMESTIC PRODUCTION OF PLATINUM GROUP METALS
(In 1,000 Troy Ounces)

	Total U.S. Consump.	Primary Production	Secondary Production
1971	1261	21	278
1972	1562	15	256
1973	1831	20	266
1974	1981	13	325
1975 (est)	1300	16	300

SOURCE: Commodities Data Summaries 1976, p. 126

TABLE 20

U.S. IMPORTS FOR CONSUMPTION
PLATINUM GROUP METALS
1971
(1,000 Troy Ounces)

	PLATINUM		PALLADIUM		OTHER	
	Troy Ounces	% Pt.	Troy Ounces	% Pd	Troy Ounces	% Other
Argentina	0.1	- -				
Australia	5.1	0.9			0.0(a)	- -
Austria			1.6	0.2		
Benelux	21.3	3.6	3.2	0.5	0.0(a)	- -
Brazil	2.5	0.4				
Canada	29.9	5.0	18.3	2.8	3.2	6.3
Columbia	24.0	4.0			2.9	5.7
Denmark	0.4	0.1	0.4	0.1		
Finland	0.8	0.1				
France	0.0(a)	- -				
Germany, West	9.4	1.6			0.3	0.6
Italy	1.2	0.2				
Japan	23.7	4.0			0.5	1.0
Mexico	4.6	0.8				
Netherlands	0.1	- -	0.6	0.1		
New Zealand	0.1	- -				
Norway	6.7	1.1	5.9	0.9		
Panama	0.0(a)	- -				
Peru	0.1	- -				
South Africa	123.2	20.7	39.1	5.9	3.4	6.7
Surinam	0.0(a)	- -				
Sweden	3.2	0.5	0.9	0.1		
Switzerland	0.0(a)	- -	0.5	0.1		
USSR	69.2	11.6	332.9	50.6	5.5	10.9
United Kingdom	268.5	45.2	254.7	38.7	34.8	68.8
	594.1	100.0	658.1	100.0	50.6	100.0

(Table 20 - cont'd)

Total Platinum Group Imports - 1,302,800 Troy Ounces

Percent of Group Imports:
Platinum - 45.6%   Palladium - 50.5%   Other - 3.9%

(a) - Less than 50 Troy Ounces

SOURCE: U.S. Bureau of Mines, Minerals Yearbook, Volume 1, 1971

TABLE 21

U.S. IMPORTS FOR CONSUMPTION
PLATINUM GROUP METALS
1972
(1,000 Troy Ounces)

	PLATINUM		PALLADIUM		OTHER	
	Troy Ounces	% Pt.	Troy Ounces	% Pd	Troy Ounces	% Other
Australia	7.4	1.1	1.0	0.1		
Benelux	15.9	2.3				
Botswana	0.3	- -				
Brazil	1.0	0.1			0.1	- -
Canada	15.3	2.2	13.5	1.5	10.8	4.5
Columbia	19.5	2.8			6.0	2.5
Costa Rica	1.2	0.2			0.2	0.1
Finland	0.7	0.1				
Germany, West	12.2	1.8	6.8	0.8	0.7	0.3
Ghana	0.1	- -				
Japan	37.3	5.4	34.3	3.8	40.2	16.6
Malawi	0.5	0.1				
Mexico	13.8	2.0			1.9	0.8
Netherlands	0.6	0.1	0.5	0.1	0.3	0.1
Neth. Antilles	0.0(a)	- -				
New Zealand	0.0(a)	- -				
Norway	8.2	1.2	15.1	1.7		
Panama	0.5	0.1			0.0(a)	- -
South Africa	116.0	16.8	111.9	12.4	9.8	4.0
Sweden	2.8	0.4				
Switzerland			2.1	0.2		
Turkey	1.6	0.2				
USSR	169.4	24.5	523.1	58.0	43.8	18.1
United Kingdom	267.2	38.6	193.8	21.5	128.7	53.1
Venezuela	0.0(a)	- -				
TOTALS	691.7	100.0	902.1	100.0	242.5	100.0

(Table 21 - cont'd)

Total Platinum Group Imports - 1,836,349 Troy Ounces

Percent of Group Imports:
Platinum - 37.7% Palladium - 49.1% Other - 13.2%

(a) - Less than 50 Troy Ounces

SOURCE: U.S. Bureau of Mines, Minerals Yearbook, Volume 1, 1972 three countries which provide the vast majority of these metals are the United Kingdom, the Soviet Union, and the Republic of South Africa.

However, as is often the case, the sources of mineral imports are not always the primary sources of the raw materials themselves. In the case of these platinum group metals, the United Kingdom merely has the refining capability and does not mine the ores. The Republic of South Africa provides the United Kingdom with almost all of its ores. Thus South Africa is the most important source of platinum group metals consumed in the United States. The world mine outputs of platinum group metals are contained in Table 22. The Soviet Union and South Africa produce between 80 to 90 percent of the world's platinum group ores. Canada is the third largest producer, but it supplies only about 10 percent of the world's output.

Future Demand

The requirement for platinum group metals within the United States is projected to expand in the next several years. The Bureau of Mines expects this increase to be about 3% through 1980.[5] In their study of the requirements for platinum group metals during the remainder of this century, the Stanford Research Institute also projected a steady rise in demand. Their model forecasted a demand

TABLE 22

WORLD MINE OUTPUT OF
ALL PLATINUM GROUP METALS
(1,000 Troy Ounces)

	1970		1971		1972	
	Troy Ounces	% of Output	Troy Ounces	% of Output	Troy Ounces	% of Output
Canada	482.4	11.4	475.2	11.6	399.0	8.6
Columbia	26.4	0.6	25.6	0.6	26.0	0.6
Ethiopia	0.3	0.0	0.2	0.0	0.2	0.0
Finland (e)	0.6	0.0	0.6	0.0	0.6	0.0
Japan	7.9	0.2	8.8	0.2	9.9	0.2
Philippines	1.2	0.0	1.5	0.0	7.5	0.2
South Africa (e)	1502.8	35.5	1254.2	30.7	1803.0	39.1
USSR (e)	2200.0	51.9	2300.0	56.3	2350.0	50.9
U.S.	17.3	0.4	18.0	0.4	17.1	0.4
TOTALS	4238.9	100.0	4084.1	100.0	4613.3	100.0

SOURCE: U.S. Bureau of Mines, Mineral Yearbook, Volume 1, 1972, p. 1053 for palladium of about 1,000,000 troy ounces by 1985 and a demand for platinum of about 850,000 troy ounces by the same year.[6] For the entire group demand was projected at 2,000,000 troy ounces by 1985 and growing to 2,600,000 troy ounces by the end of the century.[7]

As the world consumption of automobiles and electronics, particularly communications, expands during the next several years, the world-wide demand for platinum metals can be expected to increase. The increasing concern for air pollution resulting from automobile emissions will likewise increase demand, as these metals are important in reducing the amount of air pollutants released. However, in compiling this study, the authors were unable to find projections of the world-wide demand for platinum group metals for the remainder of this century.

The known world-wide resources of platinum group metals is about 1,800,000,000 troy ounces. Of this, about 600,000,000 are considered to be reserves. The Bureau of Mines estimates that these world reserves will last for well over 125 years based on their projected primary demand for the period of 1975-2000.[8] If all currently known resources were exploitable well over 350 years of demand would be satisfied.

The situation surrounding domestic resources is somewhat more acute. Currently known United States' resources amount to about 210,000,000 troy ounces of which only about 7,000,000 can be considered reserves and currently exploitable.[9] Current domestic reserves of platinum group metals represent only 3 to 4 times the current annual requirements for primary ores. Total domestic resources are relatively plentiful, but because of the low grade of the ores they are largely undeveloped. Significant increases in the relative prices of platinum ores would be required before these resources would be developed. The domestic demand for platinum group metals will, of necessity, probably always be satisfied largely by imports.

Geopolitical Concerns

Although world-wide reserves of platinum group metals appear to be more than ample in meeting a growing international demand, the United States will have to rely heavily on foreign sources to meet its domestic requirements. Access to the varied sources of supply could be interrupted and thereby disrupt the orderly flow of these vital minerals. Two of the primary means by which this flow could be interrupted is by the United States being denied access to the raw materials by the supplying nation itself or by the obstruction of the transportation network by a third power. Both of these aspects concerning the security of sources will be reviewed as they pertain to the platinum group metals.

Both the attitudes and stability of principle raw material suppliers must be closely examined to determine the security of these sources. The nations supplying the United States with platinum group metals are primarily the United Kingdom, South Africa, and the Soviet Union. As was previously noted, the United Kingdom obtains its raw materials substantially from South Africa. Consequently, difficulties in United States' relations with either South Africa or the Soviet Union could have a significant impact on the availability of platinum group metals in the required quantities.

Although South Africa directly supplied only 12.7% of the United States' demand for platinum group metals in 1971 and 12.9% in 1972, over 50% of the total United States' demand in 1971 and 45% in 1972 were satisfied by ores originating from South Africa. This relationship is evident from Tables 20 and 21 when South African and United Kingdom imports are combined. Thus, South Africa is clearly our most important source of platinum group minerals, particularly of platinum itself. Additionally, the Bureau of Mines estimates that about 70% of the world's reserves of platinum are located in South Africa.[10] Thus, that country will continue to be a prime source of platinum group metals into the foreseeable future.

While South Africa is the most highly industrialized nation in Africa and has in the past been a highly reliable supplier of many minerals to the United States and other industrialized nations, its future as such is becoming increasingly one of concern. This concern was brought out in detail in the chapter on chromium. The problems of obtaining a reliable supply of platinum group metals is merely a portion of this overall and much larger problem.

The second largest supplier of the United States' requirements for platinum group metals is the Soviet Union. As indicated in Tables 20 and 21, the Soviet Union supplied about 31% of our total 1971 demand for platinum group metals and about 40% in 1972. However, the Soviet Union is the primary source of palladium, having supplied 51% of the total 1971 demand and 58% of the 1972. The Bureau of Mines estimates that about 150,000 troy ounces, or 25% of the currently known world's reserves, are located in the Soviet Union.[11] Thus the Soviet Union should, like South Africa, maintain its position as an important source of platinum group metals, particularly palladium.

The Soviet Union continues to present significant economic, political, and ideological problems for the United States. The potential effects of these concerns on mineral imports were detailed in a previous chapter.

However, the reliability of the Soviet Union as a long term supplier of platinum group metals remains problematic.

Canada, Columbia, Japan, and the Benelux nations are the next most important suppliers of platinum group metals. Individually, or even collectively, they provide only a small portion of the total United States' imports for consumption. In 1971 these nations supplied less than 10% of the United States' import requirements and in 1972 their contribution was only 10.5%.

The relatively small amounts of platinum group metals imported from sources other than South Africa or Russia, preclude these nations from individually disrupting the flow of platinum minerals to any significant degree. To impact the price or quantity of United States' imports, these nations would have to join with either South Africa or the Soviet Union in a cartel type of action. Such an organization is highly unlikely because of the political and ideological differences between the smaller suppliers and the Soviet Union, and the general expression of international disapproval of extensive relations with South Africa.

One scenario, while not currently likely, does seem possible whereby an effective political cartel of many of the world's minerals, including the platinum group metals, could be established. This situation would require the overthrow of the current South African government, as a possible result of its interracial policies, and the establishment of a government sympathetic to the Soviet Union. Under such conditions, a highly effective producer group could be easily established that could control the flow and prices of several internationally important minerals.

In addition to being denied access by the supplying nations, the sources of the platinum metals might be interrupted through the interdiction of transportation routes by third nations. Both the Soviet Union and South Africa have several ports with relatively good transportation systems between their mineral deposits and the ports. Thus the sea lines of communication present potentially the greatest opportunity for disrupting the flow of platinum group metals between the supplying nations and the western industrialized nations. During past wars, these sea routes have been vulnerable to enemy action and this would likely be the case in future conventional conflicts of a protracted nature. All significant imports of platinum group metals with the exception of those from Canada, and possibly those from Colombia, would be susceptable to interdiction of sea routes. A glance back to Tables 20 and 21 will show that substantially all of the

United States' imports require some ocean transportation, and most require the transit of the Atlantic Ocean. The Atlantic sea routes, during periods of armed conflict, would present a particularly vulnerable area for disrupting needed mineral shipments and thereby significantly impact the United States' industrial base if the conflict were broad and protracted.

Potential for Cartel Action

Over and above the geopolitical factors that might affect the availability of platinum group metals there is one largely economic factor that could significantly affect the price and availability of these minerals. The producing companies themselves rather than their governments could not act to restrict supplies or increase prices. Only five producing companies mine the vast majority of the free world's platinum, and the potential for collusive pricing practices is quite high.[12] There is some evidence that platinum producers have cooperated in the past in attempts to control the price of platinum itself. However, it appears that most previous actions were aimed at stabilizing prices and discouraging the development of platinum substitutes.[13] These producers realize that chemical processes could be developed that did not use platinum or substitutes using less platinum could be developed within the electrical industry. Although platinum demand is today relatively insensitive to price because its low cost relative to the total cost of the end items, substitutes would be developed and demand depressed if drastic long term price increases were to be experienced.

Substitution

Within the platinum group, palladium can be substituted for platinum in many of its electrical and electronic uses. Gold, silver, and tungsten are potential substitutes for platinum group metals in specific electrical and electronic uses, but they too are costly and their properties vary somewhat. Thus, some investment in the development of these substitutes would be necessary. "Other materials or processes could be substituted for the use of platinum catalysts in petroleum refining and chemicals, but this would be a lengthy and expensive endeavor."[14] The availability of substitute materials or processes although costly, has been an important factor in stabilizing the price and availability of platinum group metals in the past and it is likely to do so in the future.

Stockpiling

Three of the platinum group metals, iridium, palladium, and platinum, have been designated as strategic materials. As such, stockpiles of these metals are maintained by the Federal Preparedness Agency to decrease the dangerous and costly dependence of the United States upon foreign sources for these materials during periods of national emergency.

As of 30 June 1975, the national stockpiles of platinum group metals contained 17,002 troy ounces of iridium, 1,254,994 troy ounces of palladium, and 452,645 troy ounces of platinum.[15] The total value of these stockpiles was about $184,500,000.

The Federal Preparedness Agency has developed objective stockpile levels for each of these metals. These objectives are based on the high priority requirements for each of these metals during the first year of a major conventional war. Adjustments have been made in each of the objectives to allow for substitution of other materials during the first year of the emergency. The current objective levels are 1,800 troy ounces of iridium, 328,500 troy ounces of palladium, and 187,500 troy ounces of platinum.[16]

Although the current stockpile inventory levels are well above the objective levels, the Federal Preparedness Agency is not reducing its inventories. Current legislation does not authorize the disposal of platinum group metals. Such disposal legislation would have to be enacted by Congress prior to the Federal Preparedness Agency reducing current stockpile levels.

Development of Domestic Sources

As indicated in Table 19, very little primary platinum group metal is produced in the United States. "Although the United States has sizeable resources of the platinum-group metals, they are undeveloped, very poorly defined, and mostly subeconomic at current prices. It is unlikely that domestic production will ever satisfy domestic demand."[17] Even as a by-product in the mining of copper, domestic production has difficulty competing with foreign sources. Increases in the relative prices of platinum group metals, or severe reductions in their availability on international markets would be required before the domestic production of primary metals would be expanded.

The refining of secondary or reprocessed platinum group metals satisfies a large portion of the domestic demand for these metals. As shown by Table 19, this secondary production has satisfied about 20% of the United States' demand from 1971 through 1975. Secondary recovery of platinum catalysts is possible with a loss of only 1% to 2% of the platinum. However, in times of emergency, this supply of platinum group metals might also be expected to diminish as the period of the emergency becomes more prolonged. As the price of primary platinum rose or its availability became restricted, substitution would result, and the source of metals for secondary reprocessing would thus become smaller. However, in the short run, this secondary production could be diverted from lower to higher priority uses and thereby alleviate the problem temporarily.

Conclusions

In ranking 74 strategic materials as to their potential for adversely influencing the United States' national security, the Stanford Research Institute ranked the platinum group metals as the third most severe problem area. Four factors contributed significantly to this high ranking: the relatively low level of domestic reserves, the high dependency on imports, the difficulty of substitution in the short run, and the vulnerability of the primary sources of platinum group metals. This high ranking appears justified, although the Stanford study may have over emphasized the difficulty of substitution. Their position on substitution is not fully consistent with that of the Bureau of Mines or the Council on International Economic Policy.

From this review, it is apparent that on a worldwide basis ample reserves of platinum group metals exist to meet future expected demand levels. While the United States' resources of platinum group metals are extensive, they are subeconomic. Thus, the known United States' reserves are very limited and if fully exploited, could not support even a reduced domestic demand for more than a few years. Even in a national emergency it would be difficult to develop these sources since much of the platinum is produced as a by-product of other mining operations.

The sources of the platinum group metals seems to be particularly vulnerable. This vulnerability is exemplified by the United States' dependence on the Soviet Union for over 50% of its palladium imports. The current political situation in the Republic of South Africa and its neighboring nations also raises serious questions as to that nation's future reliability as the ultimate supplier of over 50% of the United States' platinum group imports.

The national stockpile objectives for the platinum group metals when combined with the domestic secondary production seem sufficient to assure the continued support of defense requirements and other high priority uses during the first year or so of a conventional armed conflict. During this period of emergency, lower priority uses would have to be curtailed or supported at a lower level. The current stockpile levels which are well above objective levels could support a more protracted conflict. However, the ability of the national stockpiles to support priority requirements during extended periods of emergency seems limited. These limitations would be acute if stockpile levels were reduced to objective levels. Given the vulnerability of our primary sources of platinum and palladium, it is not unlikely that an ideological or political confrontation well below the level of armed conflict might result in the denial of needed platinum group metals for periods well in excess of one year. This would require the costly and lengthly development of substitutes. The national stockpile objectives for these metals should give greater consideration to the vulnerability of sources of supply and the potential for protracted emergencies below the level of armed conflict. Our relations with both South Africa and the Soviet Union and the outlook for future relations should play an important role in developing stockpile levels for iridium, palladium and platinum.

Two other actions that would seem both feasible and appropriate would be to encourage the development of materials or processes to replace the platinum group metals and to encourage the domestic and international exploration for new sources of these metals. Since substitutions of materials and processes seem to be available, the government might consider the funding of research directed towards economically exploiting these possibilities. This would be one means of alleviating our reliance on the platinum group metals, and the national stockpiles. Likewise, the encouragement of exploration might alleviate this potential problem by discovering and developing new and potentially less vulnerable sources of these needed metals. New sources of platinum could be important during an extended emergency, since United States' reserves are very limited and current prime sources seem particularly vulnerable to disruption. No efforts directed towards either of the above purposes were found in researching this paper.

A short term disruption of the flow of platinum group metals from foreign sources would have little impact on the United States' national security, but a long run disruption would be costly, if possible, to overcome and could seriously threaten the national security because of the many basic uses of the platinum group metals.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Recently several authors have written books or articles describing the many and varied problems that the world, and in particular the United States, faces as regards the consumption of minerals. The tone of these writings has normally been diminishing supplies of minerals, increasing demand for these same minerals and the ensuing problems which must inevitably result from these intersecting conditions. The methodology used by these authors has often been to identify problems affecting specific minerals and from these to generalize the cupply and demand relationships of all mineral resources.

This paper has attempted to pursue the tone of previous writings while avoiding at least part of the preceeding methodology. In so doing, it has recognized that specific supply, demand, and access problems do exist as regards the United States' consumption of chromium, cobalt, and the platinum group metals. It has analyzed each of their specific problems and attempted to identify the most advantageous means of meeting their specific challenge. It has not, however, attempted to cover the broader area of minerals in general which is commonly addressed.

As a result of this detailed, as opposed to comprehensive approach to the problem, certain conclusions and recommendations relative to the specific minerals studied have been reached. Additionally, although the sample of minerals studied was small, certain hypotheses have been formed which may prove applicable to many different minerals. These conclusions, recommendations and hypothesis will now be summarized in terms of the specific minerals studied.

Chromium. This study concluded that adequate reserves of chromite ores exist to support projected United States' and world-wide consumption until well into the next century. It further concluded that presently recoverable reserves are almost exclusively confined to the Asian and African continents and the Philippines Archipelago. The United States presently has no chromite ores which are economically recoverable and thus is wholly dependent on imports of chromium to meet her domestic consumption needs. South Africa, the Soviet Union, Rhodesia, Turkey and the Philippines are the principal producers of chromite ores and could in theory deny the United States an adequate supply of essential chromium through cartel-like actions. While possible, such action is presently considered quite unlikely for several reasons. Chief among these reasons is the need for cooperation and concerned action between the Soviet Union and a South African/Rhodesian coalition. Such agreement appears unlikely in the foreseeable future because of the extensive political and economic differences which exist between the Soviet Union and South Africa/Rhodesia as a group. The existing United States' stockpile of chromium is a second major reason.

Short run interruptions through cartel-like actions are likely to be ineffective. The stockpile presently contains sufficient chromium, in several forms, to meet high priority national needs for approximately three years. Thus, any cartel faces the loss of revenues for a period of up to three years before they could apply effective leverage against the United States. This stockpile supply also affords an additional benefit of allowing time to develop substitutes for chromium or to reestablish domestic production of chromium using existing sub-economic domestic ores. The recently established stockpile objective, a one year supply of chromium, would reduce the on hand quantity by two-thirds. This change appears to be unwise because of the proven difficulties in substitution and in the time necessary to establish domestic production. For this reason, a return to a three year stockpile objective appears advisable to support United States' commercial and military needs for chromium. If this action is taken, the outlook for a satisfactory long term supply of chromium appears highly favorable, under all circumstances, short of a major outbreak in hostilities.

Cobalt. Among the more specific conclusions reached concerning the availability of cobalt were that ample reserves exist to assure the long run supply of this metal to the United States. Both world and domestic resources seem adequate to meet projected international and United States' demand for several hundred years to come. However, domestic resources are currently subeconomic. Therefore, at present, there is no domestic production of cobalt, and disruptions in the flow of cobalt imports of a short term nature could result. The most likely manner in which the flow of cobalt could be seriously interrupted is through a deterioration of relations with Zaire, the largest exporter of cobalt, or through the interdiction of transportation systems by a third power. The recent problems in Angola and Rhodesia, when viewed in the light of an increased Soviet naval presence in the area, seem to raise the potential for such disruption in the flow of cobalt. The United States' strategic stockpile currently maintains sufficient cobalt to satisfy the high priority national needs for cobalt for more than one year. This should be sufficient to cover most emergencies since during a protracted emergency high priority requirements for cobalt might be satisfied by developing current sub-economic domestic resources. Current national planning and control concerning cobalt consumption and stockpiling appears adequate. Some substitution of nickel for cobalt is possible, further alleviating the potential problems. While cobalt is critical to both the defense and private sectors of the economy, the potential for serious problems arising in the near future because of disruptions in the importation of this particular metal is small.

<u>Platinum Group</u>. The problem of assuring an adequate and uninterrupted supply of the platinum group of metals is somewhat more acute than that of cobalt. While world reserves of the platinum metals are plentiful, domestic reserves are sparse and could not satisfy even high priority needs of the United States for more than a few years. Substantially all of the United States' requirements for platinum group metals are met by the importing of metal originating from either the Republic of South Africa or the Soviet Union, or by the domestic reprocessing of scrap or secondary metal. Political turmoil or armed conflict because of the apartheid issue could

damage, or at least disrupt, the economic structure of South Africa, thereby jeopardizing our prime supply of platinum group metals. Likewise, an ideological or political confrontation with the Soviet Union might close this source of supply. The Federal Preparedness Agency has established a stockpile objective for the platinum group metals equivalent to one year's high priority use of these metals. This objective level, although substantially below the current actual stockpile level, would meet the criteria that the stockpile satisfy United States' demand for the first year of an armed conflict. However, in the case of the platinum group metals, disruptions of well over one year could be experienced as a result of problems that would not likely involve the United States in armed conflict. Since the sources of these metals seem to be vulnerable to lengthy interruptions, a stockpile level substantially larger than the current objective stockpile level seems appropriate for the platinum group minerals. To further alleviate the potential for problems concerning the availability of these metals, two other actions appear worthy of note. Research aimed at finding economic substitutes for the platinum group metals or the processes that require them as a catalyst should be encouraged. Likewise, the exploration and development for new diversified and potentially less vulnerable sources of platinum might be fostered. While the defense uses of the platinum group metals are not as extensive as some other minerals, the extended interruption in their availability would adversely impact the United States' national interests. Because of our almost total dependence on imports and the high level of vulnerability of the sources, platinum group metals present a high potential for future critical shortages of needed materials.

General Conclusions. Although the number of minerals reviewed in this study is limited, certain preliminary conclusions or hypotheses can be reached regarding the more all encompassing problem of mineral consumption in general.

First, the problem of mineral shortages, while serious, is a problem of specific shortages, not general. Solutions to these individual problems must address the specific shortage problems.

Secondly, the extent of the mineral shortage problem is probably less than is popularly publicized. While only three minerals were considered in this study, they were among those genrally regarded to present significant problems to the national security. In each case studied, several means were available to alleviate the potential for problems. In the short-run, these have primarily involved stockpiling of minerals and the limited use of substitutions. In the long-run, changes in technology such as the possibility of extraction of minerals from the sea or the development of additional substitute materials or processes will offer additional solutions. Finally, as the international supply of a specific mineral lags its demand, the relative price of that mineral must inevitably rise, and thereby increase the economically recoverable reserves of that mineral. This price increase would simultaneously reduce the demand for this mineral and further alleviate the problem of mineral shortage.

Finally, our reliance on several imported strategic minerals, essential to maintaining a strong economy clearly indicates the necessity of a comprehensive foreign policy with supplying nations that considers economic interdependency.

Recommendations for Further Study. Of necessity, this study has been extremely limited. Only three minerals were examined and there are many others that present potential shortage problems which could significantly impact the United States' national security. Each of these minerals require further detailed study to prevent future critical shortages from arising, which could threaten United States' national security. This study could serve as a format for these further studies.

Alternatively, the problem as it affects imports might be examined from a predominantly foreign policy or international relations aspect, whereby the impact of the total mineral imports from one or more nations might be examined for its implication on United States' national security. Whatever methodology is employed, it is first necessary to understand that the problem of resource availability is not insoluble as suggested by General Lagovskiy's "weak link". The problem is indeed complex and involves numerous interrelated economic, political, geographic, and social factors. Once this realization is reached, this nation must evaluate all factors affecting the availability of a specific mineral and select an optimum program for ensuring its continued availability. Such a program must be dynamic and adaptable to changes in the relevant factors. Thus, it is an enduring challenge to the United States.

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